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Technical
Information for
Problem
Spills

ETHYLENE GLYCOL

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ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The manual has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

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ETHYLENE GLYCOL

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

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Environmental Protection Service
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FOREWORD

The Environmental and Technical Information for Problem Spills (Enviro TIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited.

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1 SUMMARY

ETHYLENE GLYCOL ($C_2H_6O_2$)

Colourless, slightly viscous liquid

SYNONYMS

Ethylene Alcohol, Ethylene Dihydrate, Glycol, Glycol Alcohol, Monoethylene Glycol, 1,2-Dihydroxyethane, 1,2-Ethanediol, 1,2-Ethandiol

TRADE NAMES

M.E.G., Macrogol 400 BPC, NCI-C00920, Tescol

IDENTIFICATION NUMBERS

UN No. No hazard label or identification required; CAS No. 107-21-1; OHM-TADS No. 7216718; STCC No. 4915105

GRADES & PURITIES

Industrial grade: >99 percent ethylene glycol

IMMEDIATE CONCERNS

Fire: Combustible

Human Health: Moderately toxic by ingestion and contact. Low toxicity by inhalation

Environment: Harmful to aquatic life in high concentrations

PHYSICAL PROPERTY DATA

State: (15°C, 1 atm): liquid
Boiling Point: 197.6°C
Melting Point: -13°C
Flammability: combustible
Flash Point: 116°C
Density: 1.1135 g/mL (20°C)
Solubility (in water): soluble in all proportions
Behaviour (in water): sinks and mixes, no reaction
Behaviour (in air): vapours are heavier than air

ENVIRONMENTAL CONCERNS

Harmful to aquatic life in high concentrations. Toxic by ingestion to animals and birds. Ethylene glycol biodegrades in water. It does not bioaccumulate or have food chain contamination potential.

HUMAN HEALTH

TLV® (Ceiling): 50 ppm (125 mg/m^3)
IDLH: 1000 ppm

Exposure Effects

Inhalation: Ethylene glycol has a low volatility. When heated, vapours can be released and result in intoxication, headache, possible loss of consciousness, and central nervous system depression

Contact: Contact with the eyes may cause irritation and conjunctivitis. Liquid absorbed by skin may cause symptoms similar to ingestion

Ingestion: May cause dizziness, abdominal pain, nausea, vomiting, intoxication, coma, and death

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Issue warning: "COMBUSTIBLE". Call fire department and notify distributor. Eliminate sources of ignition including traffic and equipment. Stop the flow and contain spill, if safe to do so. Avoid contact with liquid. Keep contaminated water from entering sewers or watercourses.

Fire Control

Use alcohol foam, dry chemical, carbon dioxide, water spray or fog to extinguish. Cool fire-exposed containers with water.

COUNTERMEASURES

Emergency Control Procedures in/on

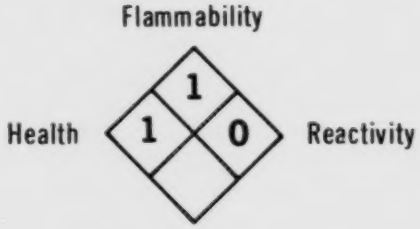
Soil: Construct barriers to contain spill or divert to impermeable holding area. Remove material with pumps or vacuum equipment. Adsorb residual liquid on natural or synthetic sorbents

Water: Contain by damming, water diversion or natural barriers. Remove water for treatment if possible or treat *in situ*

NAS HAZARD RATING

Category	Rating
Fire	1
Health	
Vapour Irritant	0
Liquid or Solid Irritant	0
Poison	1
Water Pollution	
Human Toxicity	2
Aquatic Toxicity	1
Aesthetic Effect	1

NFPA HAZARD CLASSIFICATION



Reactivity

Other Chemicals	2
Water	0
Self-reaction	0

2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

Appearance	Colourless, slightly viscous liquid (Dow MSDS 1978)
Usual shipping state	Liquid (Dow MSDS 1978)
Physical state at 15°C, 1 atm	Liquid
Melting point	-13°C (Kirk-Othmer 1980)
Boiling point	197.6°C (Kirk-Othmer 1980)
Vapour pressure	0.008 kPa (20°C) (Kirk-Othmer 1980)

Densities

Density	1.1135 g/mL (20°C) (Kirk-Othmer 1980)
Specific gravity	Liquid (water = 1): 1.1088 (20°/4°C) (CRC 1980) Vapour (air = 1): 2.14 (Verschueren 1984)

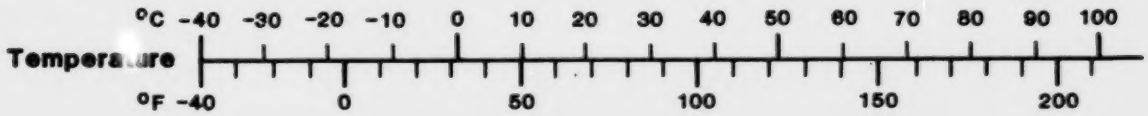
Fire Properties

Flammability	Combustible liquid (NFPA 1978)
Flash point	116°C (Kirk-Othmer 1980; Olin PD 1980)
Autoignition temperature	398°C (NFPA 1978) 410°C (Ullmann 1975)
Burning rate	1.0 mm/min (CHRIS 1978)
Lower flammability limit	3.2 percent (v/v) (NFPA 1978)
Heat of combustion	-1189.5 kJ/mole (25°C) (Kirk-Othmer 1980)
Combustion products	Carbon dioxide and water (CRC 1980)

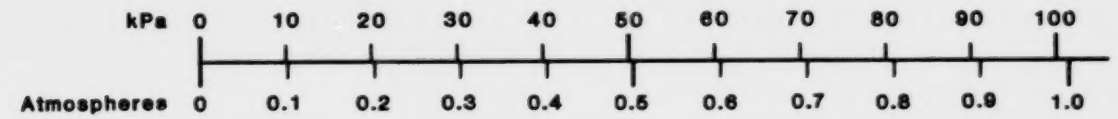
Other Properties

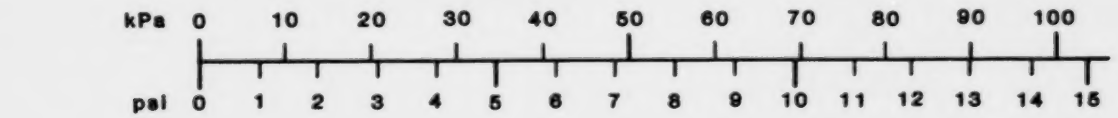
Molecular weight of pure substance	62.07 (CRC 1980)
Constituent components of typical commercial grade	>99 percent ethylene glycol, remainder water (Olin PD 1980; Kirk-Othmer 1980)
Refractive index	1.4318 (20°C) (CRC 1980)
Viscosity	33.6 mPa•s (10°C) (Olin PD 1980) 19.8 mPa•s (20°C) (Kirk-Othmer 1980)
Liquid interfacial tension with air	48.4 mN/m (20°C) (Kirk-Othmer 1980)

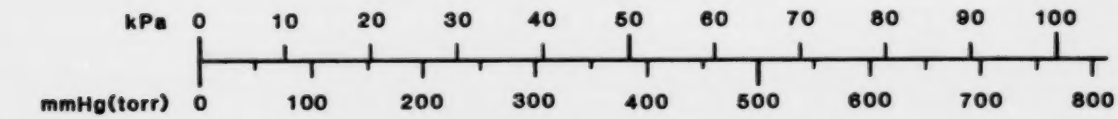
Hygroscopicity	Hygroscopic (Olin PD 1980) Absorbs twice its weight of water at 100 percent relative humidity
Latent heat of fusion	11.63 kJ/mole (at melting point) (Kirk-Othmer 1980)
Latent heat of sublimation	65.6 kJ/mole (25°C) (Lange's Handbook 1979)
Latent heat of vaporization	52.2 kJ/mole (at boiling point) (Kirk-Othmer 1980)
Heat of formation	-455.0 kJ/mole (25°C) (Sussex 1977)
Heat of solution	-27.2 J/g (17°C) (Merck 1976)
Heat capacity	
constant pressure (Cp)	149.3 J/(mole·°C) (19.8°C) (Kirk-Othmer 1980) 97 J/mole·°C) (ideal gas at 25°C) (Kirk-Othmer 1980)
constant volume (Cv)	136 J/(mole·°C) (20°C) (Perry 1973; CHRIS 1978)
Critical pressure	6515.7 kPa (Kirk-Othmer 1980)
Critical temperature	372°C (Kirk-Othmer 1980)
Coefficient of thermal expansion	0.62×10^{-3}/°C (20°C) (cubical) (Ullmann 1975)
Thermal conductivity	0.2609 W/(m·K) (Olin PD 1980)
Saturation concentration	0.65 g/m^3 (30°C) (Verschueren 1984) 0.204 g/m^3 (79 ppm) (20°C) (Miller 1979)
Eutectic compositions	50 percent (w/w) aqueous solution (f.p. -36.6°C) (Kirk-Othmer 1978)
Log_{10} octanol/water partition coefficient	-1.93 (Hansch and Leo 1979)
Solubility	
In water	Miscible in all proportions (Dow MSDS 1978)
In other common materials	Miscible with diethyl ether (7.89 g/100 mL), low aliphatic alcohols, aldehydes and ketones (Olin PD 1980). Miscible with acetic acid, acetone and ethanol (CRC 1980)
Weight-to-Volume Conversion Factor	1 ppm = 2.74 mg/m^3



Pressure 1 kPa = 1 000 Pa







Viscosity

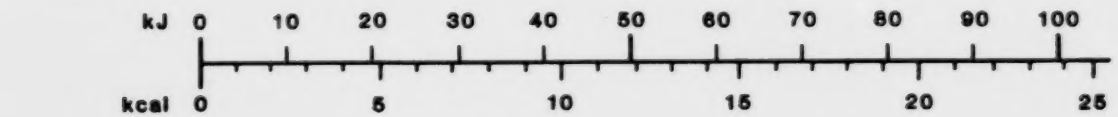
Dynamic 1 Pa·s = 1 000 centipoise (cP)

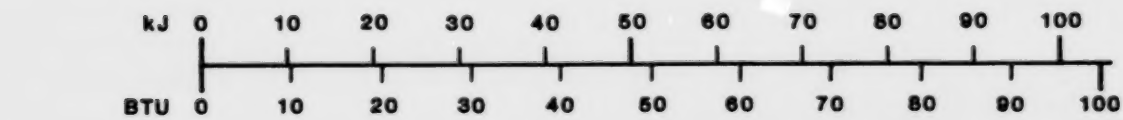
Kinematic 1 m^2/s = 1 000 000 centistokes (cSt)

Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat) 1 kJ = 1 000 J





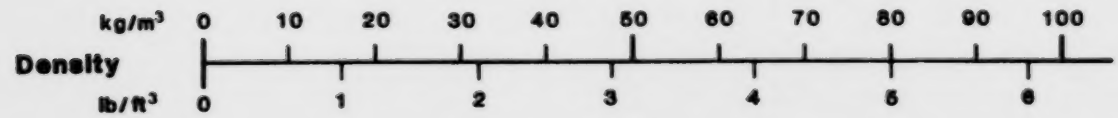


FIGURE 1

ETHYLENE GLYCOL

PHASE DIAGRAM OF THE $HOCH_2CH_2OH \cdot H_2O$ SYSTEM

Reference: ISH 1977

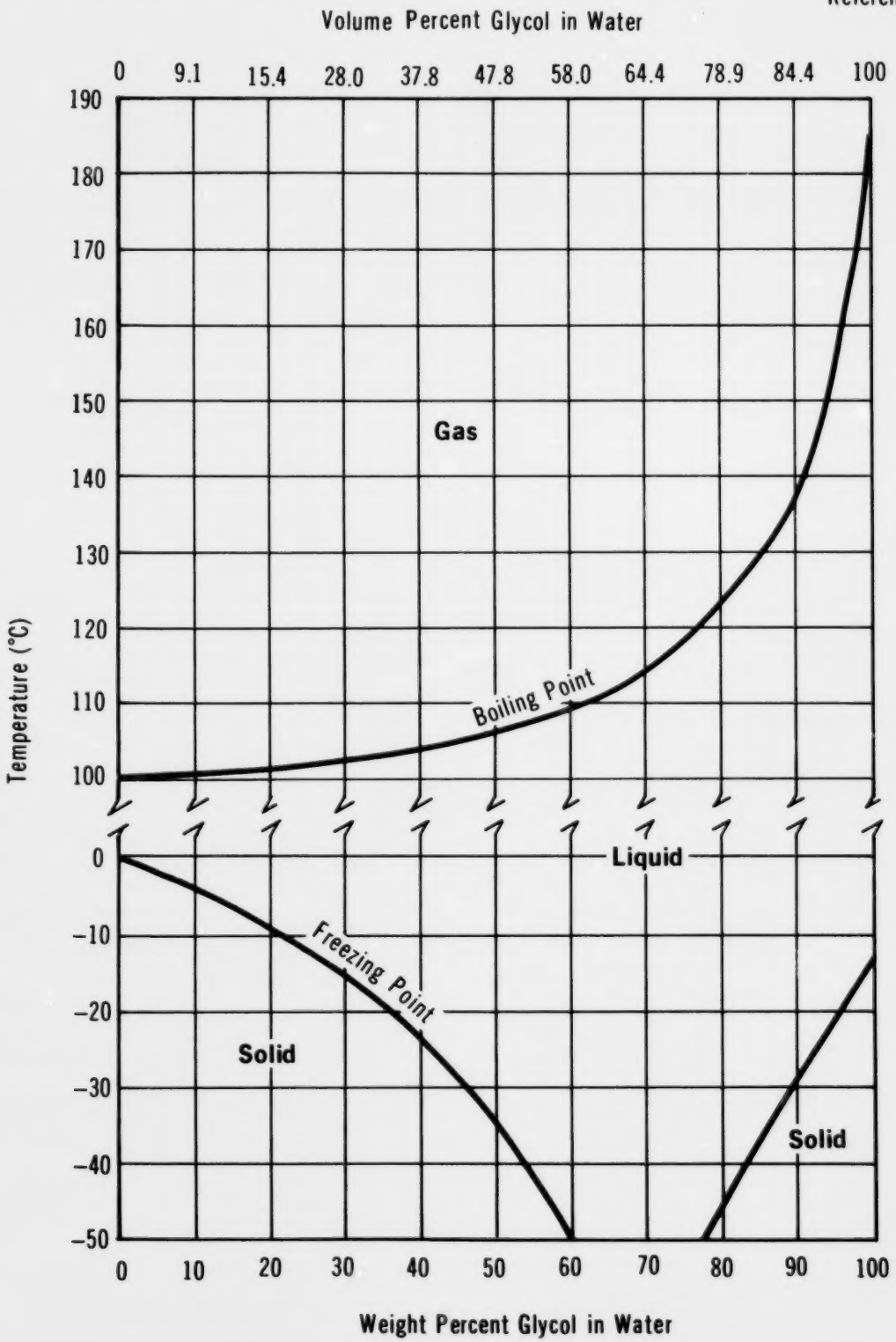


FIGURE 2

ETHYLENE GLYCOL

VAPOUR PRESSURE VS TEMPERATURE

Reference: ISH 1977

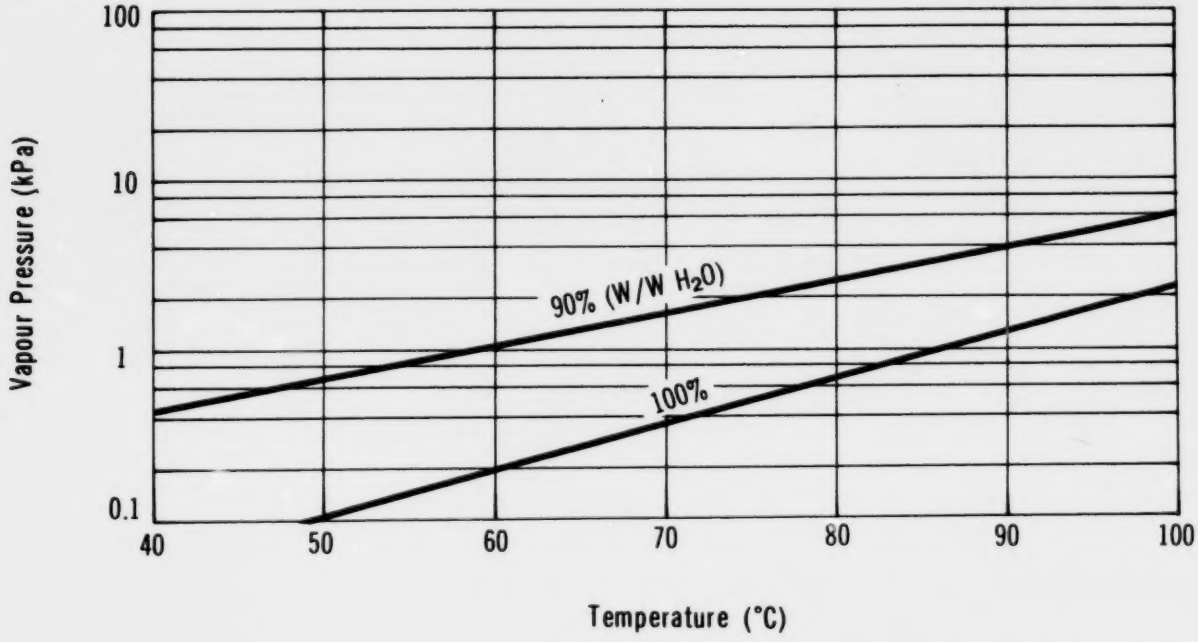


FIGURE 3

ETHYLENE GLYCOL

LIQUID DENSITY vs TEMPERATURE

Reference: ISH 1977

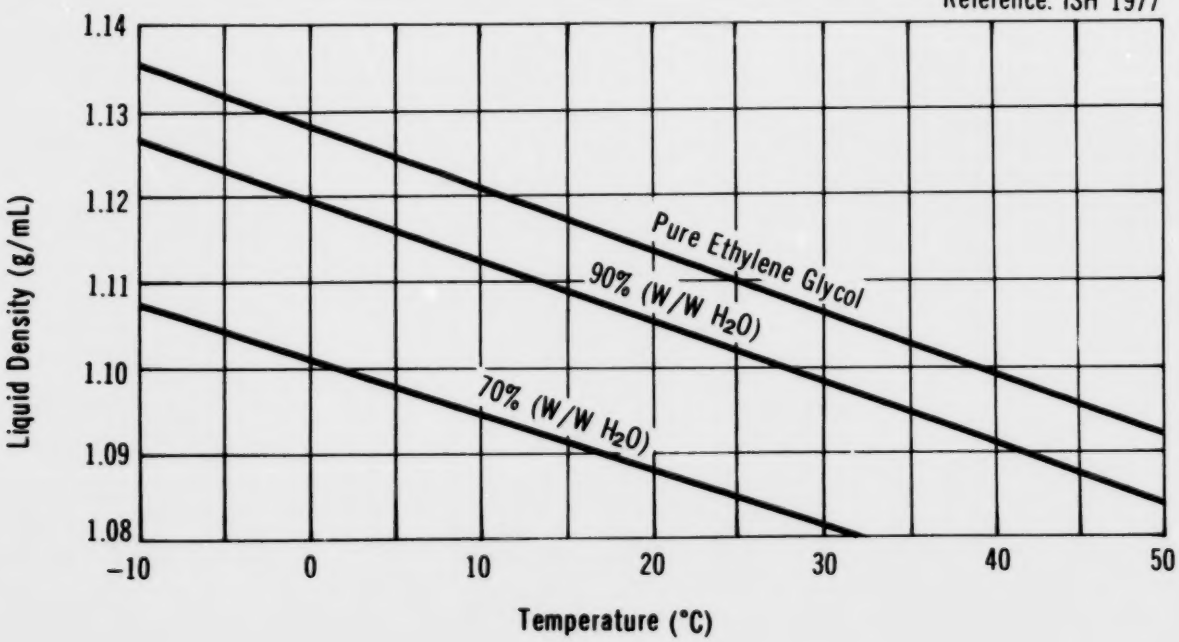
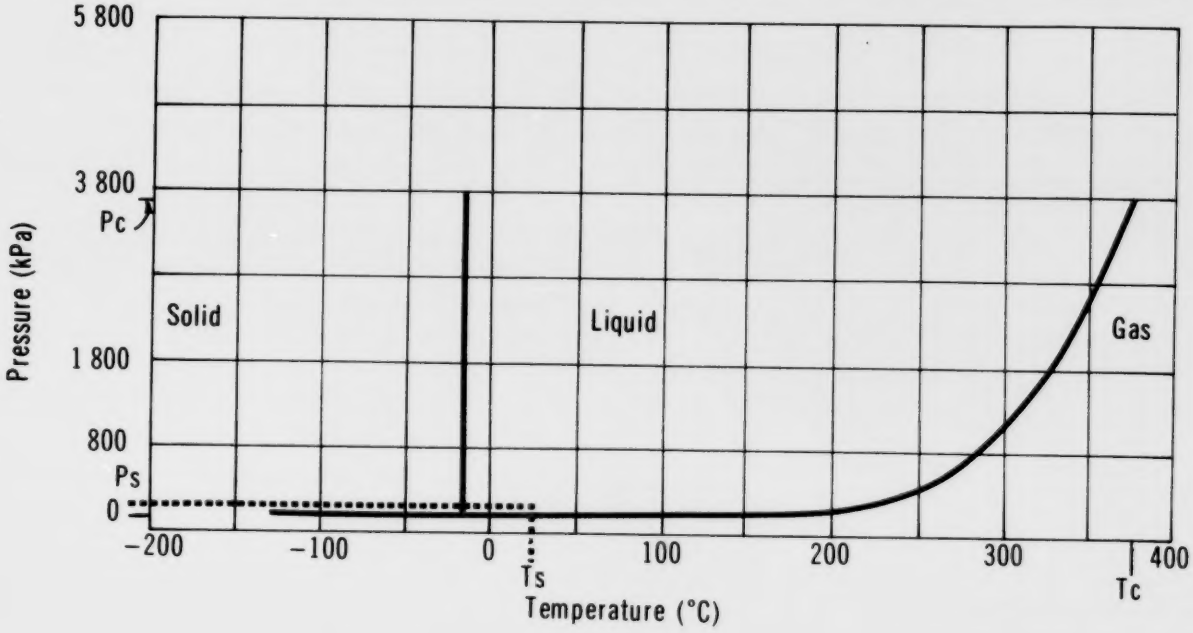


FIGURE 4

ETHYLENE GLYCOL

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities

Ethylene glycol is available in a variety of grades; the most common grade is industrial (or commercial or technical) with a purity of 99.0 percent. The following are some specifications for industrial and polyester grades (Miller 1979):

	Industrial Grade	Polyester Grade
Purity (percent)	99.0	>99.0
Acidity (as percent acetic acid)	0.005	0.005
Water (percent w/w)	0.2	0.08
Ash (percent w/w)	0.005	0.005
Diethylene Glycol (percent)	0.5	0.08
Iron (ppm maximum)	NA	0.07

Deicers for airport use contain a substantial amount of ethylene glycol. Data on two typical commercial formulations are presented below (Jank 1974):

	Dow	UCAR
Water (percent)	50	5
Ethylene Glycol (percent)	32	56
Propylene Glycol (percent)	16	38
Inhibitor (percent)	2	1
pH	8.0	8.7
BOD (mg/L)	362×10^3	712×10^3

3.2 Domestic Manufacturers (Corpus 1983; CBG 1980)

These are corporate headquarters' addresses and are not intended as spill response contacts.

Dow Chemical Canada Inc.
Box 1012, Modeland Road
Sarnia, Ontario
N7T 7K7
(519) 339-3131

Union Carbide Canada Ltd.
123 Eglinton Avenue East
Toronto, Ontario
M4P 1J3
(416) 487-1311

3.3 Other Suppliers (Corpus 1983; CBG 1980; Scott 1979)

International Chemical Canada Ltd.
P.O. Box 385
Mississauga, Ontario
L6V 2L3
(416) 453-4234

May and Baker Canada Inc.
6557 Mississauga Road
Mississauga, Ontario
L5N 1A6
(416) 821-4450

Mitsui & Co. (Canada) Inc.
Royal Bank Plaza, South Tower
Suite 3333, P.O. Box 53
Toronto, Ontario
M5J 2J2
(416) 865-0330

3.4 Major Transportation Routes

Current Canadian production of ethylene glycol is located primarily in Fort Saskatchewan, Alberta (59 percent of total production). Other facilities are located in Montreal, Quebec (28 percent of total production), and Sarnia, Ontario (13 percent of total production). The product is shipped by rail and truck over most of Canada.

3.5 Production Levels (Corpus 1983)

Company, Plant Location		Nameplate Capacity kilotonnes/yr (1982)
Dow Chemical Canada, Sarnia, Ont.		45
Dow Chemical, Ft. Saskatchewan, Alta.		204
Union Carbide Canada, Montreal, Que.		95
	TOTAL	344
Domestic Production (1982)		169
Imports (1982)		-
	TOTAL SUPPLY	169

3.6 Future Development (Corpus 1983)

Union Carbide Canada is building a world-scale glycol plant at Prentiss, Alberta, to be in production by late 1984, with a capacity of 230 kt/yr.

3.7 Manufacture of Ethylene Glycol (Shreve 1977; Kirk-Othmer 1980).

3.7.1 General. Two methods are presently used for the production of ethylene glycol: one uses ethylene chlorohydrin as an intermediate; a second, more recent innovation, uses the reaction of ethylene with oxygen and water.

3.7.2 Manufacturing Process. Ethylene glycol production using ethylene chlorohydrin as an intermediate combines the chlorohydrin with sodium bicarbonate as follows:

$$CH_2{:}CH_2 + Cl_2 + H_2O \longrightarrow HOCH_2CH_2Cl + HCl \qquad \text{(Step 1)}$$

$$HOCH_2CH_2Cl + NaHCO_3 \longrightarrow HOCH_2CH_2OH + NaCl + CO_2 \qquad \text{(Step 2)}$$

Step 1 is completed by passing ethylene and chlorine into water at 10-49°C. The resulting chlorohydrin solution is concentrated to 35-40 percent and reacted with the sodium bicarbonate in Step 2. The glycol solution is concentrated by distillation.

Alternatively, ethylene oxide may be produced from the chlorohydrin by heating with caustic soda or hydrated lime. This can then be hydrated to glycol in the presence of a weak acid. The second production method is defined by the following reactions:

$$CH_2{:}CH_2 + 1/2\ O_2 \longrightarrow CH_2\overset{O}{\diagup\!\diagdown}CH_2$$

$$CH_2\overset{O}{\diagup\!\diagdown}CH_2 + H_2O \longrightarrow HOCH_2CH_2OH$$

Ethylene, oxygen and recycle gas are charged to a tubular reactor filled with a silver catalyst (or sulphuric acid) operating at 200-300°C. Ethylene oxide is recovered from this operation by absorption in water. This stream is further reacted with water in the presence of acid at 50-100°C. Glycol is extracted from the resulting effluent.

3.8 Major Uses in Canada (Corpus 1983)

Ethylene glycol is used in the manufacture of antifreeze mixtures, polyethylene terephthalate, glycol esters, solvents, dessicants, explosives, and cellulose film, in the production of polyester fibres, and in gas processing. In 1982, 81 percent of domestic demand was sold as ethylene glycol, 11 percent was exported, and the remainder was used directly in the production of polyglycols, ethoxylates, etc. It is estimated that half of the product sold as ethylene glycol is used in antifreeze products.

3.9 Major Buyers in Canada (Corpus 1983; CBG 1980)

Air Canada, Most Major Canadian Cities
A & K Petro-Chem, Weston, Ont.
Alkanyl Chemicals, Mississauga, Ont.
Amoco Canada Petroleum, Mississauga, Ont.

Apco Industries, Toronto, Ont.
Ar'liss Chemical, Montreal, Que.
Ashland Chemical/Solvents, Mississauga, Ont.
Bate Chemical, Toronto, Ont.
BCL Canada, Cornwall, Ont.
Becton Dickenson Canada, Mississauga, Ont.
British American Chemical, Vancouver, B.C.
Canada Colors & Chemicals, Toronto, Ont.
Canada Printing Ink, Toronto, Ont.
Canadian Pacific Airlines, Most Major Cities in Canada.
Canadian Alcolac, Valleyfield, Que.
Celanese Canada, Sarnia, Ont; Edmonton, Alta.
Chevron Standard, Kaybob, Alta.
Chinook Chemical, Sarnia, Ont.
C-I-L, McMasterville, Que.
C-I-L Paints, Toronto, Ont.
Ciscochem, Brampton, Ont.
Commercial Alcohols, Montreal, Que.
Cote Chemicals, Montreal, Que.
E. Crossfield, Windfall, Alta.
Dominion Cisco Industries, Toronto, Ont.
Domtar (CDC), Longford Mills, Ont.
Du Pont Canada, Shawinigan, Que.
General Printing Ink, Weston, Ont.
Glidden (SCM), Toronto, Ont.
Griffith Laboratories, Scarborough, Ont.
Gulf Canada, Nevis, Alta.
Hall Chemical, Montreal, Que.
Harrisons & Crosfield, Toronto, Ont.
Hart Chemical, Guelph, Ont.
Hudson Bay Oil & Gas, Kaybob, Alta.
Inmont Canada, Toronto, Ont.
International Chemical, Brampton, Ont.
International Paints, Montreal, Que.
Iron Ore of Canada, Sept-Iles, Que.
Kert Chemical, Toronto, Ont.
Kingsley & Keith, Toronto, Ont.
Laurentide Chemicals, Shawinigan, Que.
Lawrason's Chemicals, London, Ont.
Lester Inks & Chemicals, Thornhill, Ont.
Millhaven Fibres, Millhaven, Ont.
Moore, Benjamin, Toronto, Ont.
Niagara Protective Coatings, Niagara Falls, Ont.
Northumberland Chemicals, Parkdale, P.E.I.
Peinture Nationale, Quebec City, Que.
PPG Industries Canada, Toronto, Ont.
Quality Oil, Montreal, Que.
Recochem, Montreal, Que.
Shefford Chemicals, Granby, Que.
Shell Canada, Toronto, Ont.
Shell Canada, Waterton, Alta.
Sherwin-Williams, Montreal, Que.

Sinclair & Valentine, Downsview, Ont.
Stanchem, Montreal, Que.
St. Lawrence Starch, Mississauga, Ont.
Stormont Chemicals, Mississauga, Ont.
Texaco Chemicals, Don Mills, Ont.
Trans Chemicals, Calgary, Alta.
Turbo Resources, Calgary, Alta.
Van Waters & Rogers, Vancouver, B.C.
Warren Packaging, Toronto, Ont.
Western Solvents, Toronto, Ont.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

4.1.1 Bulk Shipment. Transportation vessels and containers under this category have been grouped under the classifications of railway tank cars and highway tank vehicles.

4.1.1.1 Railway tank cars. Ethylene glycol is not specifically regulated under CTC/DOT regulations. As it is combustible and has a low vapour pressure, a number of tank cars are permitted as shown in Table 2.

TABLE 2 RAILWAY TANK CAR SPECIFICATIONS

CTC/DOT* Specification Number	Description
103W	Steel fusion-welded tank with dome. Uninsulated or insulated. General service. 2% dome. Safety valves (414 kPa) (60 psi). Bottom outlet or washout optional.
111A60W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A60F1	Steel forge-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A100W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Bottom outlet or washout optional. Test pressure 690 kPa (100 psi).

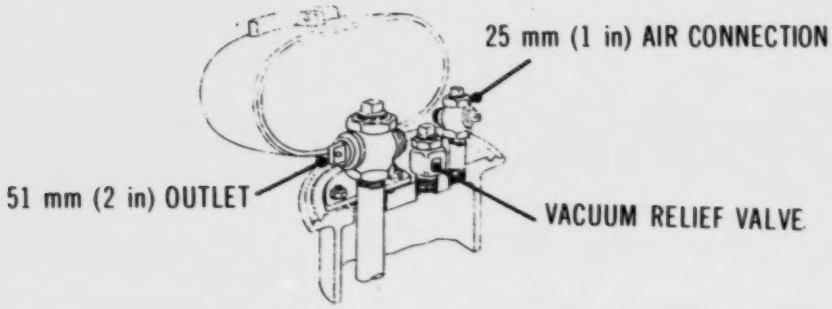
* Canadian Transport Commission and Department of Transportation (U.S.)

The most commonly used car is the 111A60W1 as illustrated in Figure 5. Table 3 indicates railway tank car details associated with this drawing. Cars are equipped for unloading by pump or gravity flow through a 152 mm (6 in.) diameter bottom outlet provided with an inner plug valve (TDGC 1980). The bottom outlet may be furnished with a steam jacket. In addition to bottom unloading, the cars may be unloaded from the top

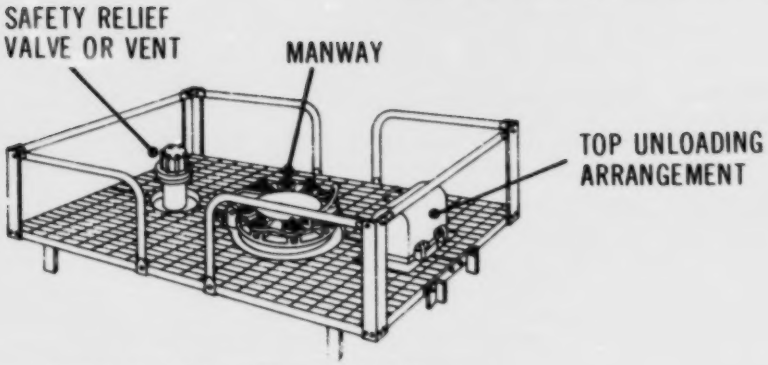
ETHYLENE GLYCOL

RAILWAY TANK CAR - CLASS 111A60W1

(Reference - TCM 1979, RTDCR 1974)



Detail of top unloading arrangement



Detail of loading platform

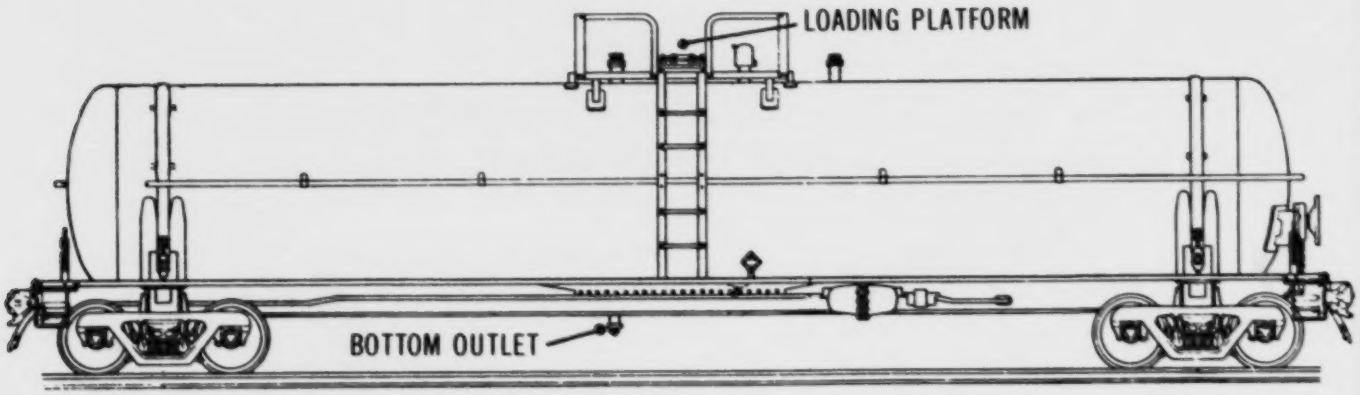


Illustration of tank car layout

TABLE 3 TYPICAL RAILWAY TANK CAR SPECIFICATIONS - CLASS 111A60W1 (TCM 1979; RTDCR 1974)

Description	Tank Car Size (Imp. Gal.)					
	16 700		17 200		20 000	
Overall						
Nominal capacity	75 700 L	(16 700 gal.)	78 000 L	(17 200 gal.)	90 900 L	(20 000 gal.)
Car weight - empty	33 900 kg	(74 700 lb.)	33 900 kg	(74 700 lb.)	38 900 kg	(85 800 lb.)
Car weight - (max.)	119 000 kg	(263 000 lb.)	83 500 kg	(184 000 lb.)	119 000 kg	(263 000 lb.)
Tank						
Material	Steel		Steel		Steel	
Thickness	11.1 mm	(7/16 in.)	11.1 mm	(7/16 in.)	11.1 mm	(7/16 in.)
Inside diameter	2.60 m	(102 in.)	2.62 m	(103 in.)	2.74	(108 in.)
Test pressure	414 kPa	(60 psi)	414 kPa	(60 psi)	414 kPa	(60 psi)
Burst pressure	1640 kPa	(240 psi)	1640 kPa	(240 psi)	1640 kPa	(240 psi)
Approximate Dimensions						
Coupled length	17 m	(57 ft.)	17 m	(57 ft.)	18 m	(60 ft.)
Length over strikers	16 m	(53 ft.)	16 m	(53 ft.)	17 m	(57 ft.)
Length of truck centres	13 m	(42 ft.)	13 m	(42 ft.)	14 m	(45 ft.)
Height to top of grating	4 m	(12 ft.)	4 m	(12 ft.)	4 m	(13 ft.)
Overall height	5 m	(15 ft.)	5 m	(15 ft.)	5 m	(15 ft.)
Overall width (over grabs)	3.2 m	(127 in.)	3.2 m	(127 in.)	3.2 m	(127 in.)
Length of grating	2-3 m	(8-10 ft.)	2-3 m	(8-10 ft.)	2-3 m	(8-10 ft.)
Width of grating	1.5-2 m	(5-6 ft.)	1.5-2 m	(5-6 ft.)	1.5-2 m	(5-6 ft.)
Loading/Unloading Fixtures						
Top Unloading						
Unloading connection	51 mm	(2 in.)	51 mm	(2 in.)	51 mm	(2 in.)
Manway/fill hole	203-356 mm	(8-14 in.)	203-356 mm	(8-14 in.)	203-356 mm	(8-14 in.)
Air connection	25-51 mm	(1-2 in.)	25-51 mm	(1-2 in.)	25-51 mm	(1-2 in.)
Bottom Unloading						
Bottom outlet	102-152 mm	(4-6 in.)	102-152 mm	(4-6 in.)	102-152 mm	(4-6 in.)
Safety Devices	Safety vent or valve					
Dome	None					
Insulation	Optional					

by air pressure (Dow TED 1978). In this case, the liquid is withdrawn through an eduction pipe which extends from the bottom of the tank to the top operating platform where it terminates with an unloading connection valve.

A safety relief valve set at 414 kPa (60 psi) is required on top of the rail car (TCM 1979). A gauging device, either the rod type or the tape type, is optional. The top unloading connection must be protected by a housing.

4.1.1.2 Tank motor vehicles. Ethylene glycol is transported by tank motor vehicles with tanks classed as nonpressure vessels (Dow TED 1978). Design pressure for such tanks does not exceed 14 kPa (2 psi). Motor vehicle tanks carrying ethylene glycol are similar to the railway tanks previously described. These highway tankers are unloaded by pump or gravity. Tank materials used are stainless steel and aluminum.

The off-loading equipment and procedures for tank motor vehicles are similar to those for railway tank cars, to be discussed later.

4.1.2 Packaging. Ethylene glycol is also transported in drums. Drums fabricated from a variety of construction materials are permitted (TDGC 1980). Table 4, describing these drums, is included. In addition to drums, ethylene glycol is transported in a wide variety of plastic bottles and metal cans.

4.2 Off-loading

4.2.1 Off-loading Equipment and Procedures for Railway Tank Cars. Prior to off-loading, certain precautions must be taken:

- The vented storage tank must be checked to make sure that it will hold the contents of the car.
- For night-time unloading, lights must have an explosion-proof rating.
- Personnel must not enter the car under any circumstances.
- Brakes must be set, wheels chocked, derails placed and caution signs displayed.
- A safe operating platform must be provided at the unloading point.
- Tools used during unloading must be spark-resistant.
- Effectively ground the tank car.

Two means of off-loading, top off-loading and bottom off-loading, are used for rail cars (Figure 7).

Proceed with top off-loading using air pressure as follows (Dow TED 1978):

- After removing the protective housing from the discharge line at the top of the car, connect the 51 mm (2 in.) unloading line.

TABLE 4 DRUMS

Type of Drum	Designation	Description	Figure No. (If Any)
Steel	1A1	Nonremovable head, reusable	6
	1A1A	1A1 with reinforced chime	6
	1A1B	1A1 with welded closure flange	6
	1A1D	1A1 with coating (other than lead)	6
	1A2	Removable head, reusable	6
	1A3	Nonremovable head, single use only	6
Monel*	TC5M		6
Aluminum	1B1	Nonremovable head	6
	1B2	Removable head	6
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (49 gal.)	
Fibreboard Drums with inner plastic receptacles	6HG1	Outer containers of convolutely wound plies of fibreboard. Inner plastic in shape of drum. Maximum capacity of 225 L (49 gal.)	

* See Section 4.3 of this report.

- Connect air pressure, 138 kPa (20 psi) maximum.
- Open the air supply valve and then the unloading connection valve.
- Once the car is empty, close the air supply valve. Open the vent valve in the air line.
- Reverse the above procedure to close up the car.

Proceed with bottom off-loading in the following manner using gravity flow or pump (Dow TED 1978):

- In cold weather, apply steam to the bottom unloading connection shown in Figure 7.
- After connecting the unloading line to the 152 mm (6 in.) bottom outlet, open the inside bottom valve by turning the valve rod handle at the top of the car.
- Off-load the car by gravity or pump.

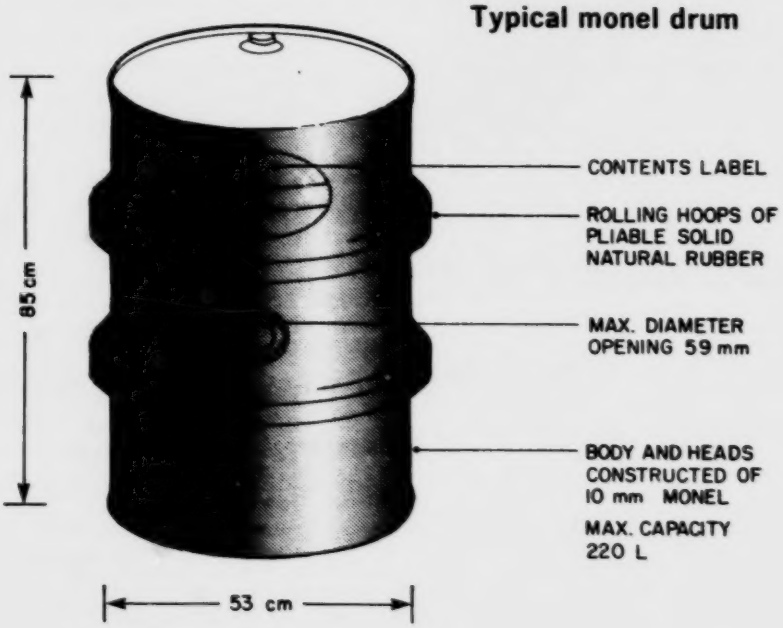
4.2.2 Specifications and Materials for Off-loading Equipment. The materials of construction for off-loading system components discussed in this section along with

FIGURE 6

ETHYLENE GLYCOL

TYPICAL DRUM CONTAINERS

Typical monel drum


85 cm
CONTENTS LABEL
ROLLING HOOPS OF PLIABLE SOLID NATURAL RUBBER
MAX. DIAMETER OPENING 59 mm
BODY AND HEADS CONSTRUCTED OF 10 mm MONEL
MAX. CAPACITY 220 L
53 cm

Typical steel drum

Typical aluminum drum

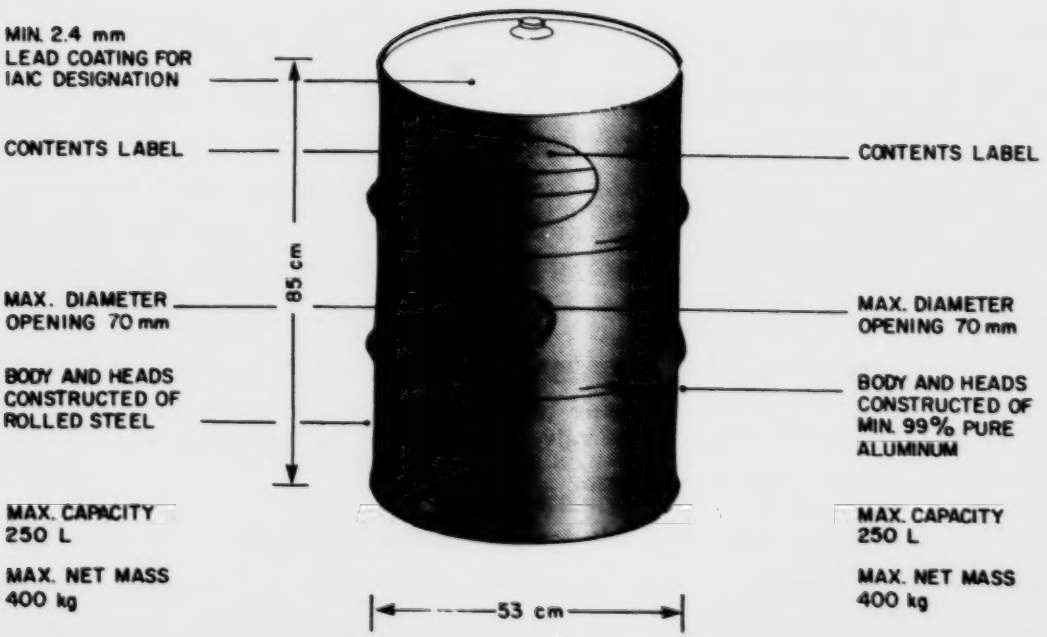
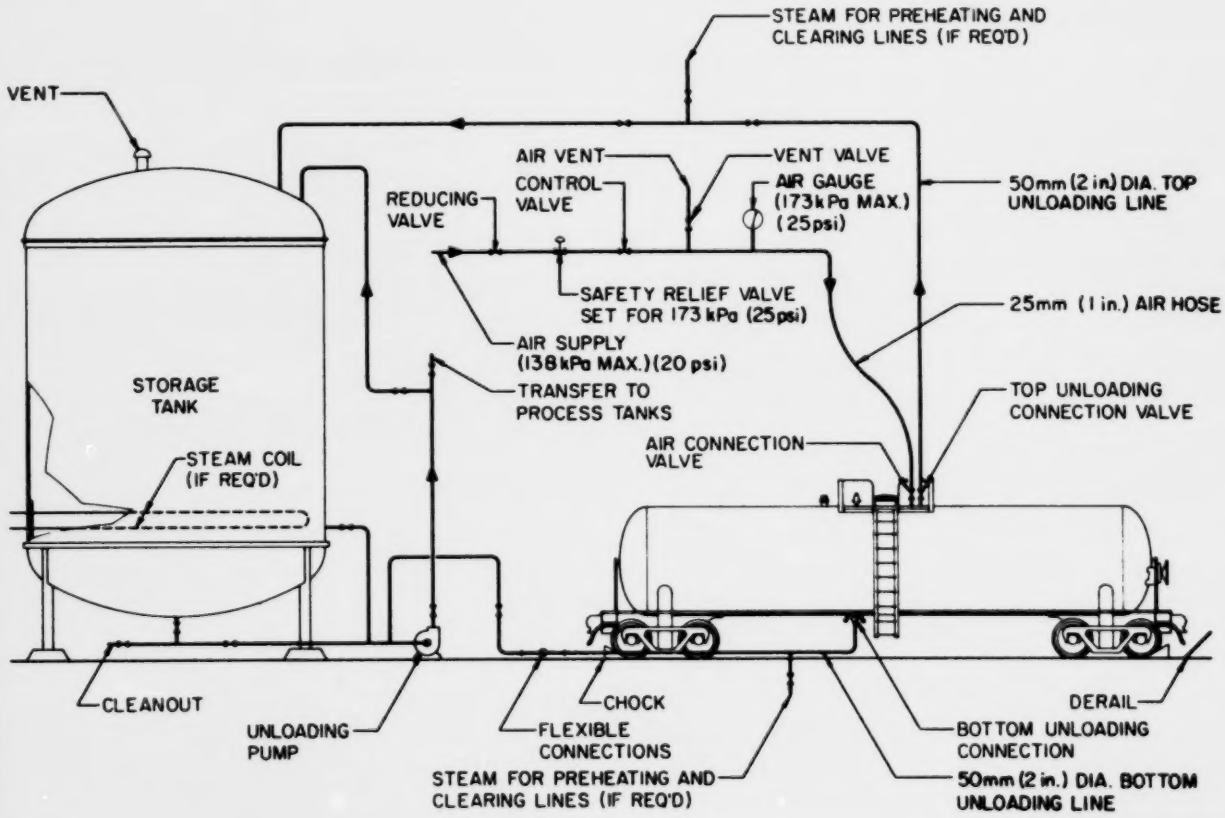

MIN. 2.4 mm LEAD COATING FOR IAIC DESIGNATION
CONTENTS LABEL
85 cm
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF ROLLED STEEL
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg
53 cm
CONTENTS LABEL
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF MIN. 99% PURE ALUMINUM
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg

FIGURE 7

ETHYLENE GLYCOL

TANK CAR UNLOADING



NOTE:

1 · FOR TOP OR BOTTOM UNLOADING METHOD SEE TEXT.

specifications refer to those generally used. It is recognized that other materials may be used for particular applications as indicated in Table 5. The components of a typical off-loading system that will be discussed include pipes and fittings, flexible connections, valves, gaskets and pumps.

Schedule 40 seamless ASTM A106 carbon steel pipes and fittings are recommended. Flanged joints should be used and these should be welded, because threaded pipes and fittings tend to leak after a very short time.

The unloading line should be 51 mm (2 in.) pipe because this is the standard fitting on tank cars. Pipe under 25 mm (1 in.), however, is not recommended. Outdoor lines must be self-draining. Saran-lined pipes and fittings may also be used (DCRG 1978).

Neoprene hoses may be used for the flexible sections of the unloading line (Dow TED 1978). Flexible bellows-type expansion joints with ASA ductile iron flanges and expansion members molded from tetrafluoroethylene resin may also be used (Dow PPS 1972).

For valving, cast iron or cast steel diaphragm valves lined with chlorinated polyether or polyvinylidene chloride resin will serve adequately (Dow PPS 1972). Viton or neoprene may be used as a gasket material at normal temperature ranges (DCRG 1978).

A centrifugal pump or positive displacement pump with "wet end" material of 316 stainless steel gives good results (Dow TED 1978). Provision must be made for draining the pump so that repairs can be made safely. The pump should be equipped with flanges at both suction and discharge openings; screw connections are more subject to leakage and should be avoided.

4.3 Compatibility with Materials of Construction

The compatibility of ethylene glycol with materials of construction is indicated in Table 5. The unbracketed abbreviations are described in Table 6. The rating system for this report is briefly described below.

Recommended:	This material will perform satisfactorily in the given application.
Conditional:	Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.
Not Recommended:	Material will be severely affected in this application and should not be used.

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings	All	23	PE* ABS* (DPPED 1967)		PE ABS (MWPP) 1978)
		107	PP (DCRG 1978)		
		60	PVC I, PVC 2 (DPPED 1967)		
		107	Chlorinated Polyether (DCRG 1978)		
		135	PVDF (DCRG 1978)		
		79	PVDC (DCRG 1978)		
2. Valves	All	100	SS 316 (JSSV 1979)		
3. Pumps	All	82	GRP with FPM "O" Ring SS, CS (Dow TED 1978)		
4. Storage Tank	All		SS, CS Aluminum (Dow TED 1978)		
5. Others	All	21	PVDF (TPS 1978)		
		22			PVC, CPVC (TPS 1978)
		23		PP (TPS 1978)	
		49			PP (TPS 1978)
		66			PVDF (TPS 1978)
		20	SS 302, SS 304 SS 316, SS 430 (ASS)	SS 410 (ASS)	

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
5. Others (cont'd)	Technically Pure	20	POM, FPM uPVC, PE PP, NR IIR, EPDM CR (GF)	CSM (GF)	NBR (GF)
	Technically Pure	60	PE, PP POM, IIR EPDM, CR FPM (GF)	uPVC NR CSM (GF)	NBR (GF)
		60	PVC (TPS 1978)		
	All	82	PP (TPS 1978)		
		85	CPVC (TPS 1978)		
		121	PVDF (TPS 1978)		
			NR*, SBR CR, NBR* IIR, CSM* Si, EPDM (GPP)		
	100%	24 to 79	Glass (CDS 1967)		

* This material has been given a lower rating in a similar application by another reference.

TABLE 6 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Aluminum
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene) Rubber
CS	Carbon Steel
CSM	Chlorosulphonated Polyethylene (Hypalon)
EPDM	Ethylene Propylene Rubber

TABLE 6 MATERIALS OF CONSTRUCTION (Cont'd)

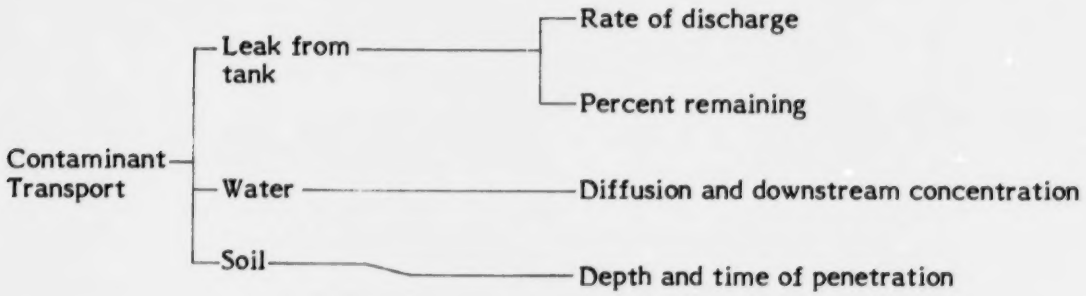
Abbreviation	Material of Construction
FPM	Fluorine Rubber (Viton)
	Glass
GRP	Glass Reinforced Vinyl Ester
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber
NR	Natural Rubber
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PVC (Followed by grade)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride (Saran)
PVDF	Polyvinylidene Fluoride
Si	Silicon
SBR	Styrene/Butadiene (GR-5, Buna S) Rubber
SS (Followed by grade)	Stainless Steel
uPVC	Unplasticized Polyvinyl Chloride

5 CONTAMINANT TRANSPORT

5.1 General Summary

When spilled in water, ethylene glycol will sink and mix. No vapours are produced. When spilled on soil, the liquid will spread on the surface and penetrate into the soil at a rate dependent on the soil type and its water content. Downward transport of the liquid toward the groundwater table may be an environmental problem. Because ethylene glycol is essentially nonvolatile, dispersion in air is not a problem.

The following factors are considered for the transport of a spill in water and soil:



It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

5.2 Leak Nomograms

5.2.1 Introduction. Ethylene glycol is commonly transported in railway tank cars as a nonpressurized liquid. While the capacities of the tank cars vary widely, one tank car size has been chosen throughout the EnviroTIPS series for development of the leak nomograms. It is approximately 2.75 m in diameter and 13.4 m long, with a carrying capacity of about 80 000 L.

If a tank car loaded with ethylene glycol is punctured on the bottom, all of the contents will drain out by gravity. The aim of the nomograms is to provide a simple means to obtain the time history of the conditions in the tank car and the venting rate of

the liquid. Because of the low volatility of ethylene glycol and the fact that the tank cars are not pressurized, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

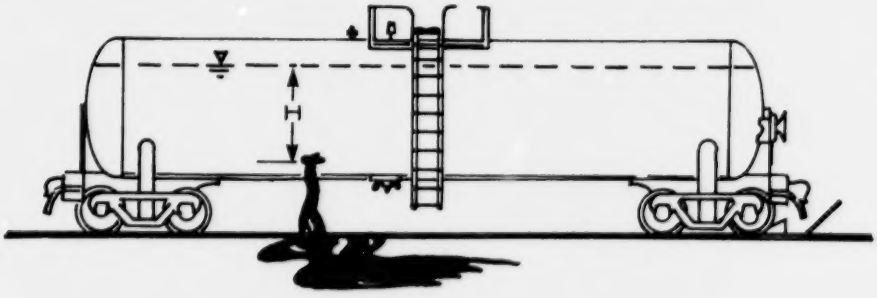


FIGURE 8 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

5.2.2 Nomograms.

5.2.2.1 Figure 9: Percent remaining versus time. Figure 9 provides a means of estimating the percent of liquid remaining in the standard tank car after the time of puncture for a number of different hole diameters. The hole diameter is actually an equivalent diameter and can be applied to a noncircular puncture.

The standard tank car is assumed to be initially full (at t=0) with a volume of about 80 000 L of ethylene glycol. The amount remaining at any time (t) is not only a function of the discharge rate over time, but also of the size and shape of the tank car.

5.2.2.2 Figure 10: Discharge rate versus time. Figure 10 provides a means of estimating the instantaneous discharge rate (L/s) at any time (t) after the time of puncture for a number of equivalent hole diameters. The nomogram is only applicable to the standard tank car size with an initial volume of 80 000 L.

5.2.3 Sample Calculations.

i) Problem A

The standard tank car (2.75 m Ø x 13.4 m long) filled with ethylene glycol has been punctured on the bottom. The equivalent diameter of the hole is 150 mm. What percent of the initial 80 000 L remains after 10 minutes?

Solution to Problem A

- Use Figure 9

FIGURE 9

ETHYLENE GLYCOL

PERCENT REMAINING VS TIME

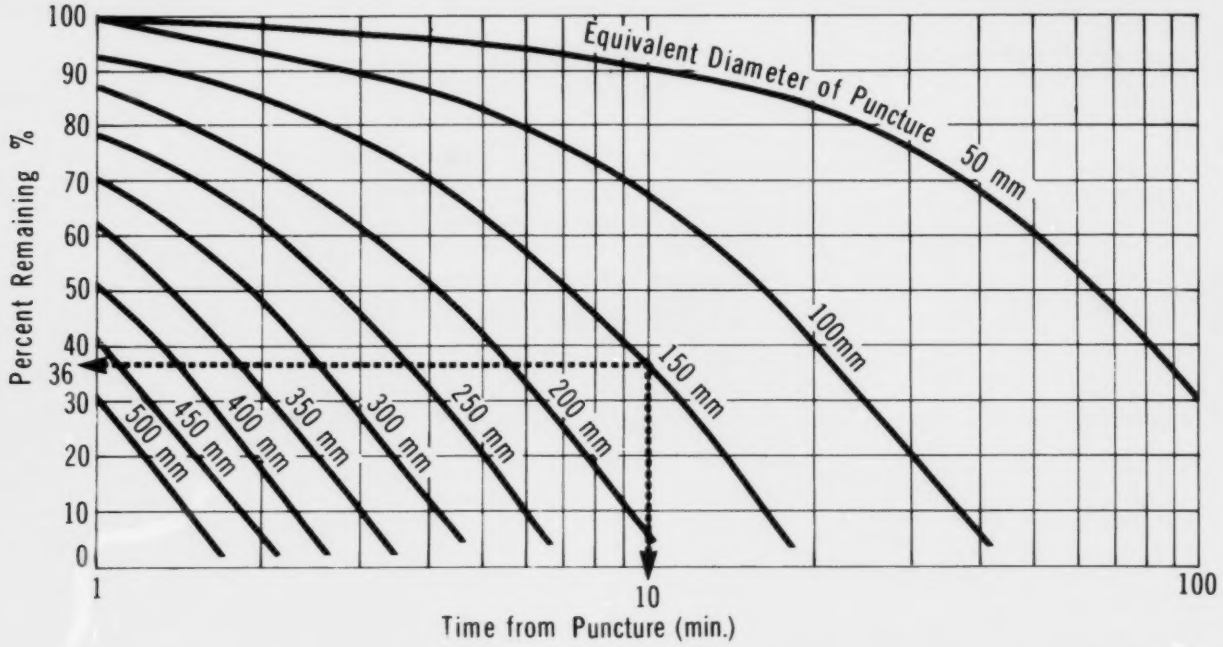
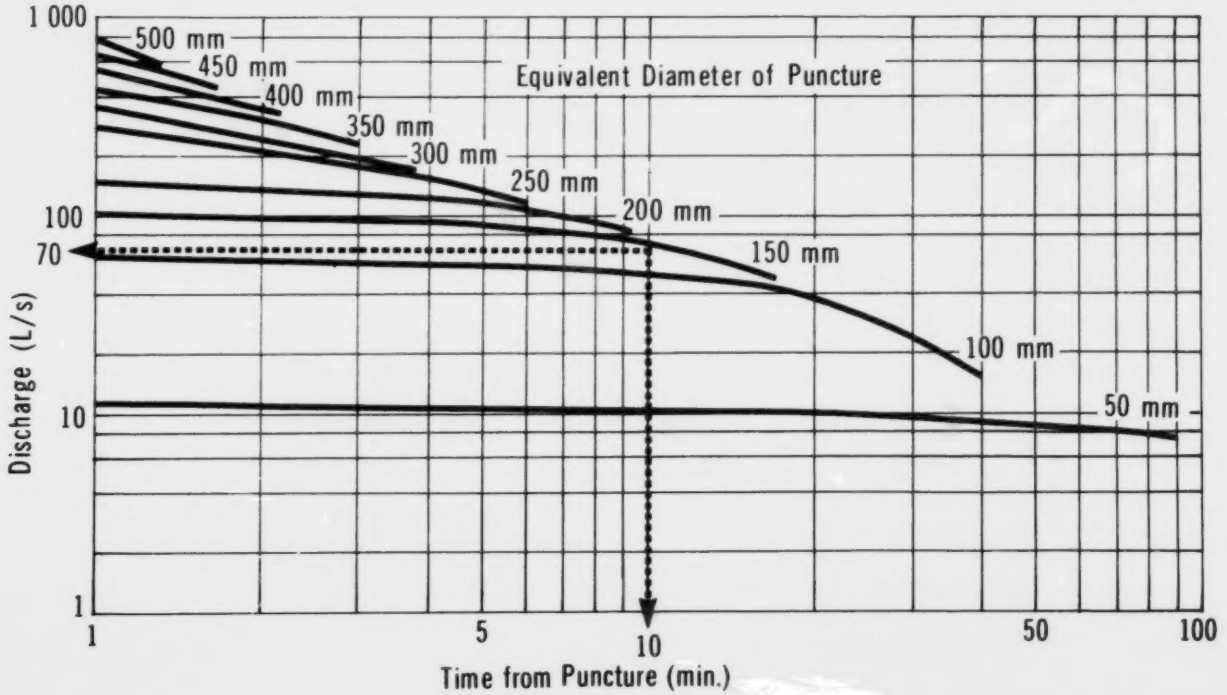


FIGURE 10

ETHYLENE GLYCOL

DISCHARGE RATE VS TIME



- With t=10 min and d=150 mm, the amount remaining is about 36 percent or 28 800 L

ii) Problem B

With the same conditions as Problem A, what is the instantaneous discharge rate from the tank 10 minutes after the accident?

Solution to Problem B

- Use Figure 10
- With t=10 min and d=150 mm, the instantaneous discharge rate = 70 L/s

5.3 Dispersion in the Air

Because ethylene glycol is relatively nonvolatile in foreseeable spill circumstances, there is no significant potential for dispersion in the air.

5.4 Behaviour in Water

5.4.1 Introduction. When spilled on a water surface, ethylene glycol will sink and mix with the water, allowing the spill to be diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence, while in calm water mixing takes place by molecular diffusion.

To estimate the pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 (W/d <100) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

5.4.2 Nomograms. The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

Non-tidal Rivers

Figure 12: time versus distance for a range of average stream velocities

Figure 13: channel width versus hydraulic radius for a range of stream depths

Figure 14: diffusion coefficient versus hydraulic radius for a range of average stream velocities

Figure 15: alpha* versus diffusion coefficient for various time intervals

Figure 16: alpha versus delta* for a range of spill sizes

Figure 17: maximum concentration versus delta for a range of river cross-sectional areas

Lakes or Still Water Bodies

Figure 18: volume versus radius for the hazard zone for a range of lake depths

Figure 19: average concentrations versus volume for the hazard zone for a range of spill sizes

The flowchart in Figure 11 outlines the steps required to estimate downstream concentrations after a spill and identifies the nomograms to be used. These nomograms (Figures 12 through 19) are described in the following subsections.

5.4.2.1 Nomograms for non-tidal rivers.

Figure 12: Time versus distance. Figure 12 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average stream velocity (U), the time (t) to reach any point of interest at some distance (X) downstream of the spill can be readily obtained from Figure 12.

Figure 13: Hydraulic radius versus channel width. The model used to estimate downstream pollutant concentration is based on an idealized rectangular channel of width (W) and depth (d).

The hydraulic radius (r) for the channel is required in order to estimate the turbulent diffusion coefficient (E). The hydraulic radius (r) is defined as the stream cross-sectional area (A) divided by the wetted perimeter (P). Figure 13 is a nomogram for computation of the hydraulic radius (r) using the width and depth of the idealized river cross-section.

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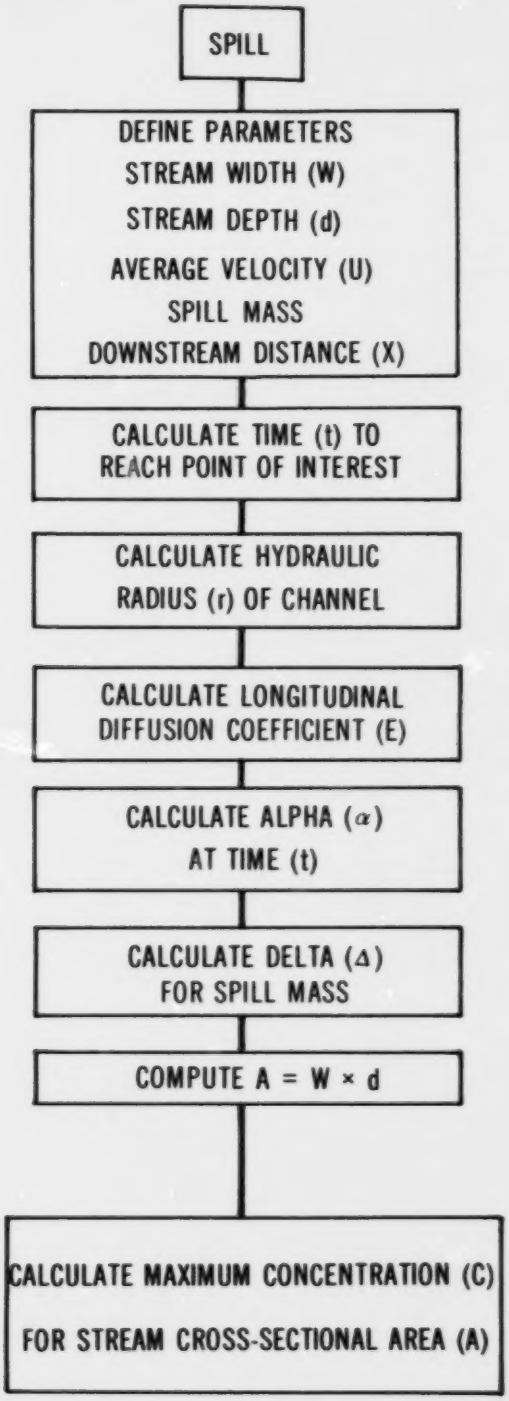
* Alpha and delta are conversion factors only and are of no significance other than to facilitate calculation of downstream concentration.

FIGURE 11

ETHYLENE GLYCOL

FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS


SPILL
DEFINE PARAMETERS
STREAM WIDTH (W)
STREAM DEPTH (d)
AVERAGE VELOCITY (U)
SPILL MASS
DOWNSTREAM DISTANCE (X)
CALCULATE TIME (t) TO REACH POINT OF INTEREST
CALCULATE HYDRAULIC RADIUS (r) OF CHANNEL
CALCULATE LONGITUDINAL DIFFUSION COEFFICIENT (E)
CALCULATE ALPHA (α) AT TIME (t)
CALCULATE DELTA (Δ) FOR SPILL MASS
COMPUTE A = W × d
CALCULATE MAXIMUM CONCENTRATION (C) FOR STREAM CROSS-SECTIONAL AREA (A)

Step 1: Observed or Estimated

W = _____ m

d = _____ m

U = _____ m/s

MASS = _____ tonnes

X = _____ m

Step 2: Use Figure 12

t = _____ minutes

Step 3: Use Figure 13

r = _____ m

Step 4: Use Figure 14

E = _____ m^2/s

Step 5: Use Figure 15

α = _____

Step 6: Use Figure 16

Δ = _____

Step 7: Compute stream cross-sectional Area (A)

A = W × d _____ m^2

Step 8: Use Figure 17

C = _____ ppm

FIGURE 12

ETHYLENE GLYCOL

TIME vs DISTANCE

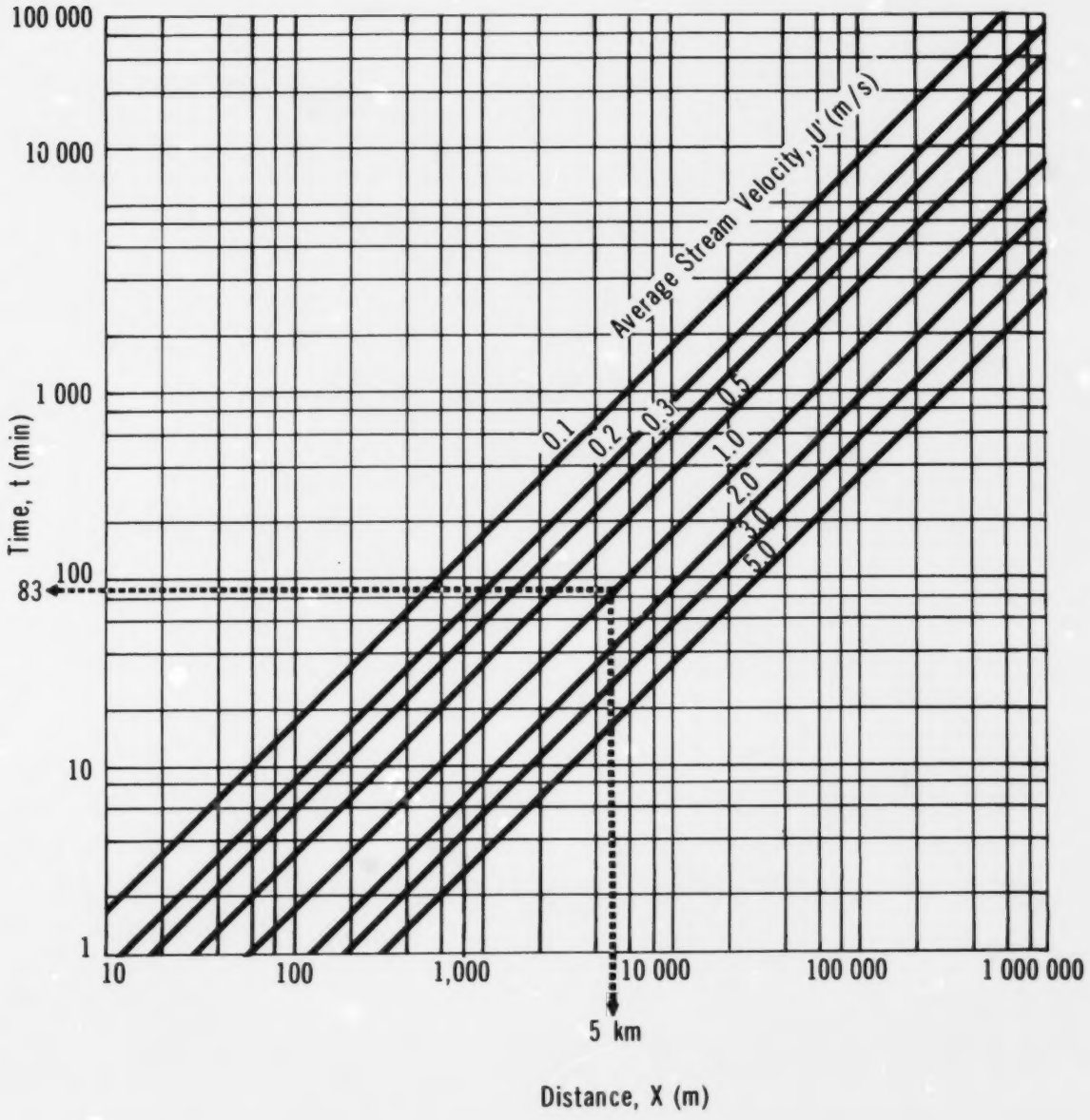


FIGURE 13

ETHYLENE GLYCOL

HYDRAULIC RADIUS VS CHANNEL WIDTH

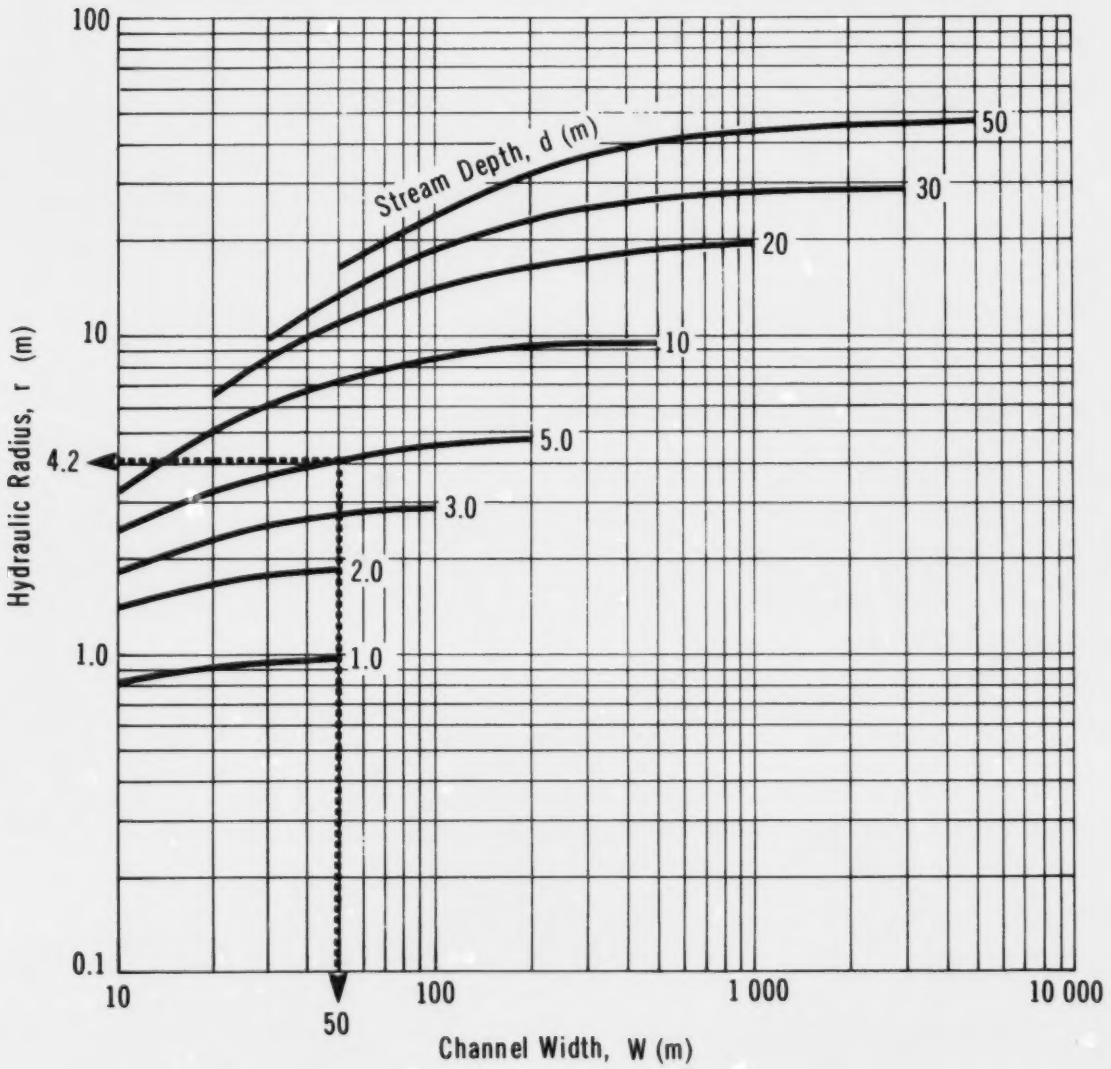


Figure 14: Hydraulic radius versus diffusion coefficient. Figure 14 permits calculation of the longitudinal diffusion coefficient (E), knowing the hydraulic radius (r) from Figure 13 and the average stream velocity (U).

Figure 15: Alpha versus diffusion coefficient. Figure 15 is used to estimate a conversion factor, alpha (α), which is a function of the diffusion coefficient (E) and the time (t) to reach the point of interest downstream of the spill.

Figure 16: Alpha versus delta. A second conversion factor, delta (Δ), must be estimated from Figure 16 to allow determination of pollutant concentration at the point of interest. Delta (Δ) is a function of alpha (α) and the spill size.

Figure 17: Maximum concentration versus delta. Figure 17 represents the final step for calculation of the maximum downstream pollutant concentration (C) at the point of interest. Using the factor delta (Δ) and knowing the stream cross-sectional area (A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 7 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

5.4.2.2 Nomograms for lakes or still water bodies.

Figure 18: Volume versus radius. The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius (r) and length (d), equivalent to the depth of the lake at the point of spill. The volume of water in the cylinder can be obtained from Figure 18. The radius (r) represents the distance from the spill to the point of interest.

Figure 19: Average concentration versus volume. For a known volume of water (within the idealized cylinder of radius (r) and length (d)), the average concentration of pollutant (C) can be obtained from Figure 19 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

5.4.3 Sample Calculations.

5.4.3.1 Pollutant concentration in non-tidal rivers. A 20 tonne spill of ethylene glycol has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

FIGURE 14

ETHYLENE GLYCOL

DIFFUSION COEFFICIENT VS HYDRAULIC RADIUS

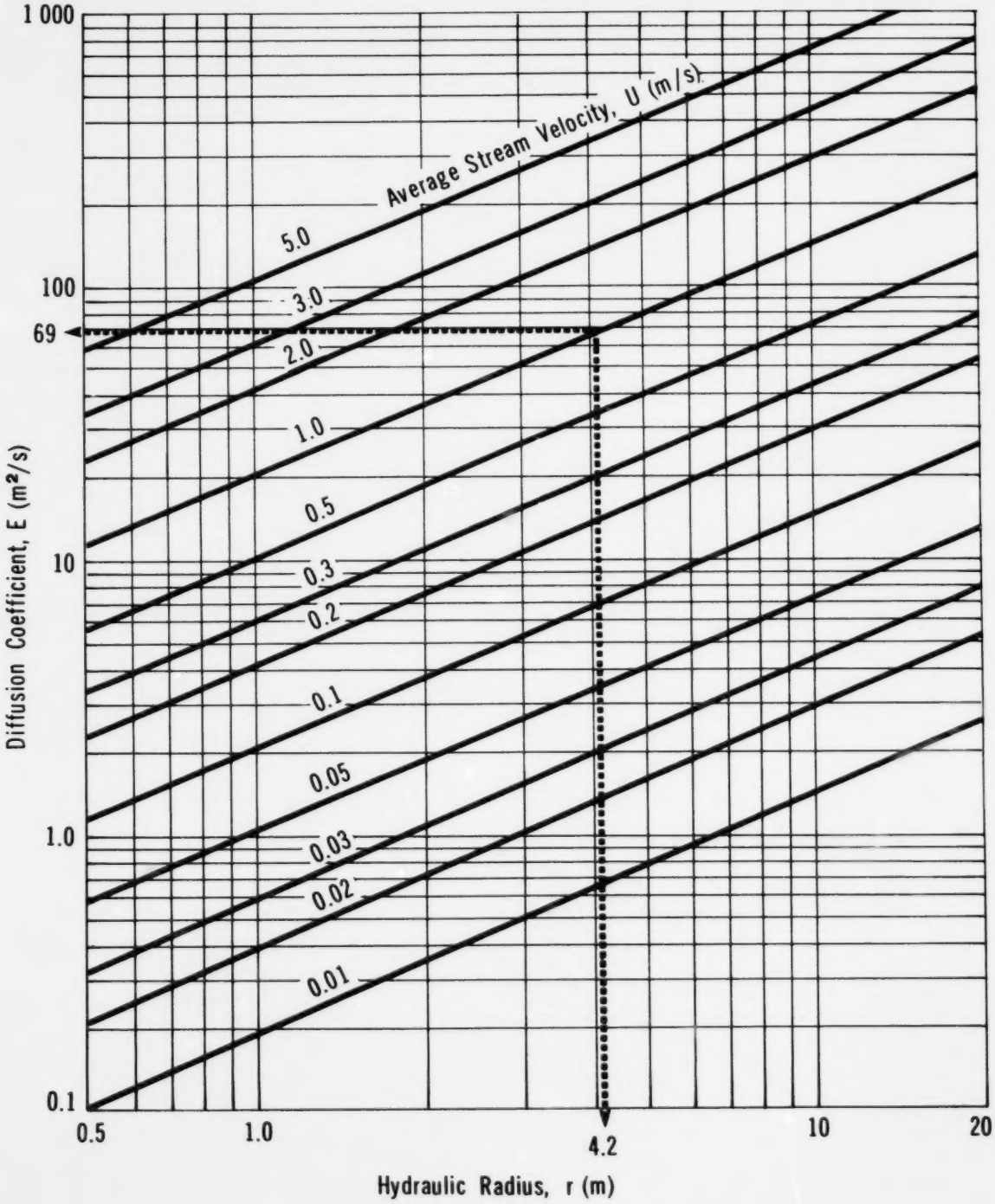


FIGURE 15

ETHYLENE GLYCOL

ALPHA vs DIFFUSION COEFFICIENT

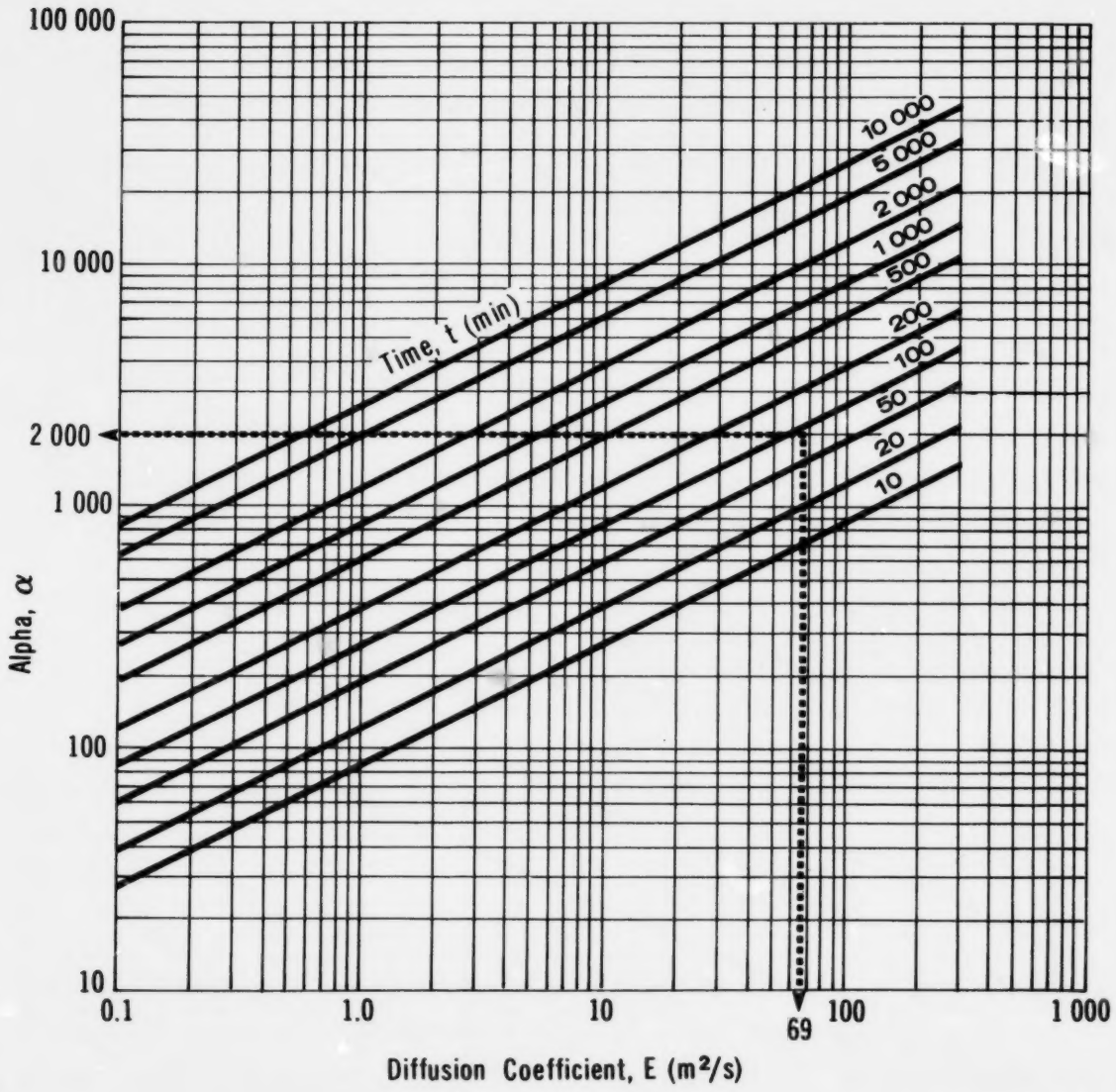


FIGURE 16

ETHYLENE GLYCOL

ALPHA vs DELTA

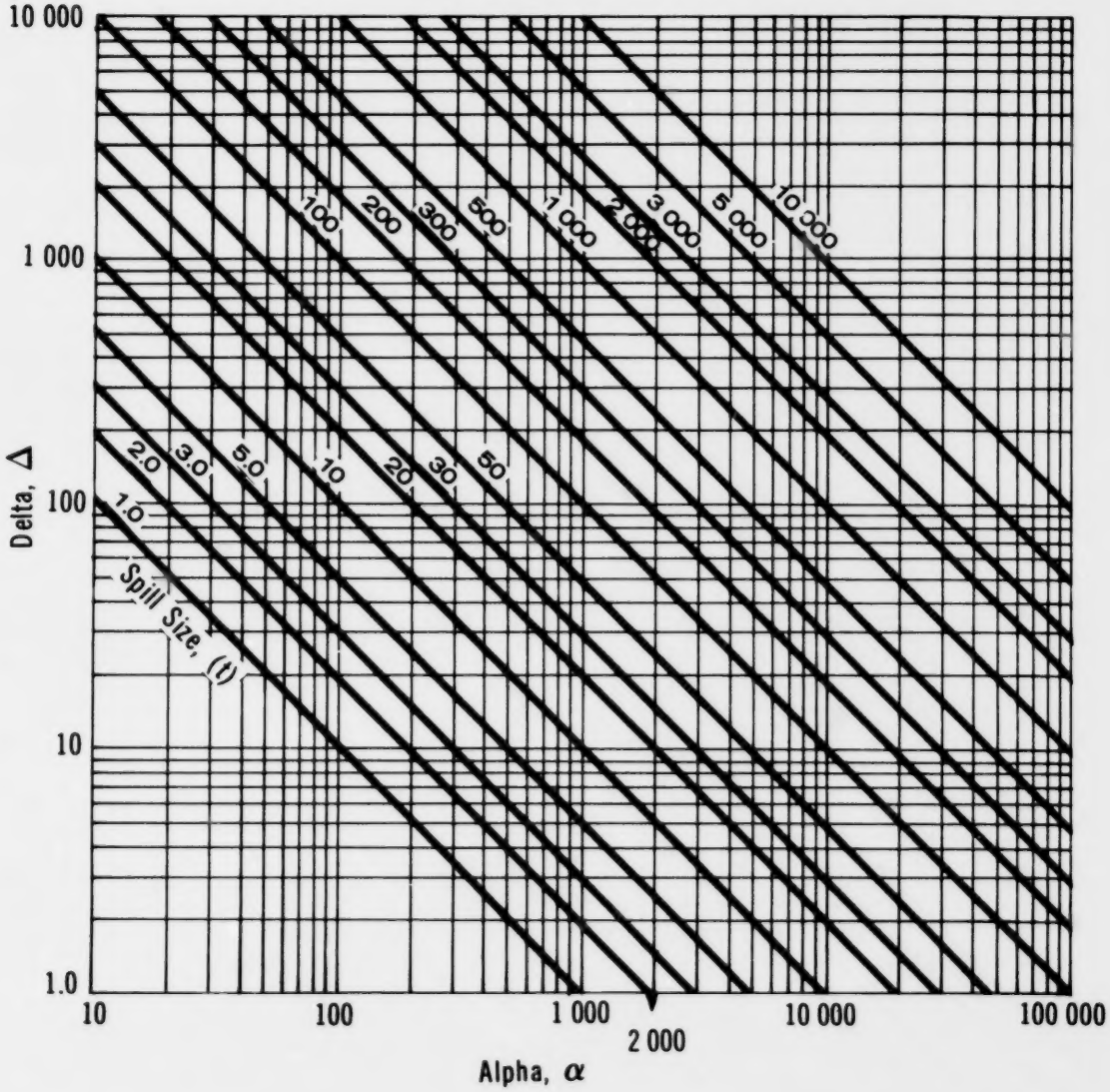


FIGURE 17

ETHYLENE GLYCOL

MAXIMUM CONCENTRATION vs DELTA

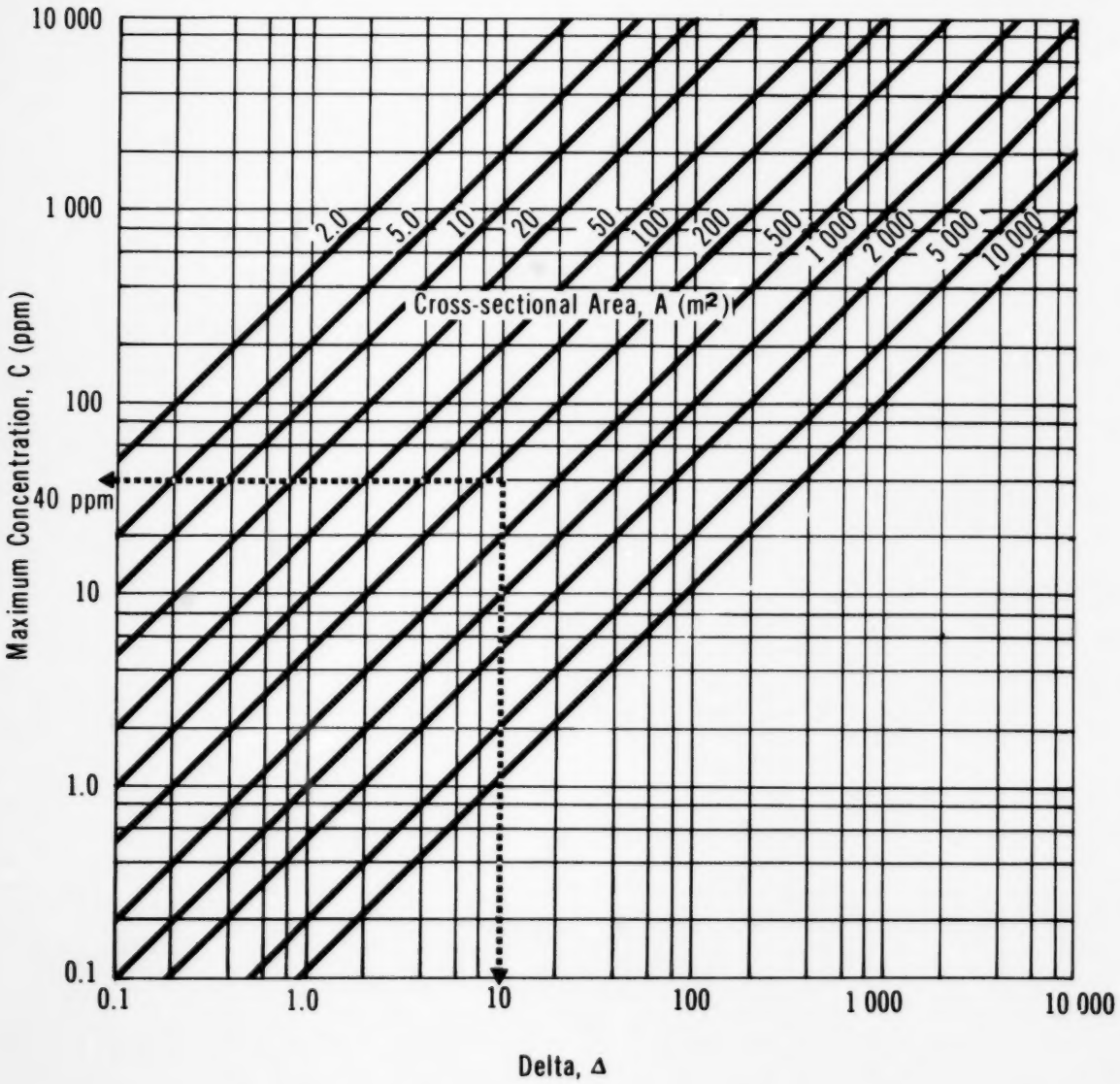


FIGURE 18

ETHYLENE GLYCOL

VOLUME vs RADIUS

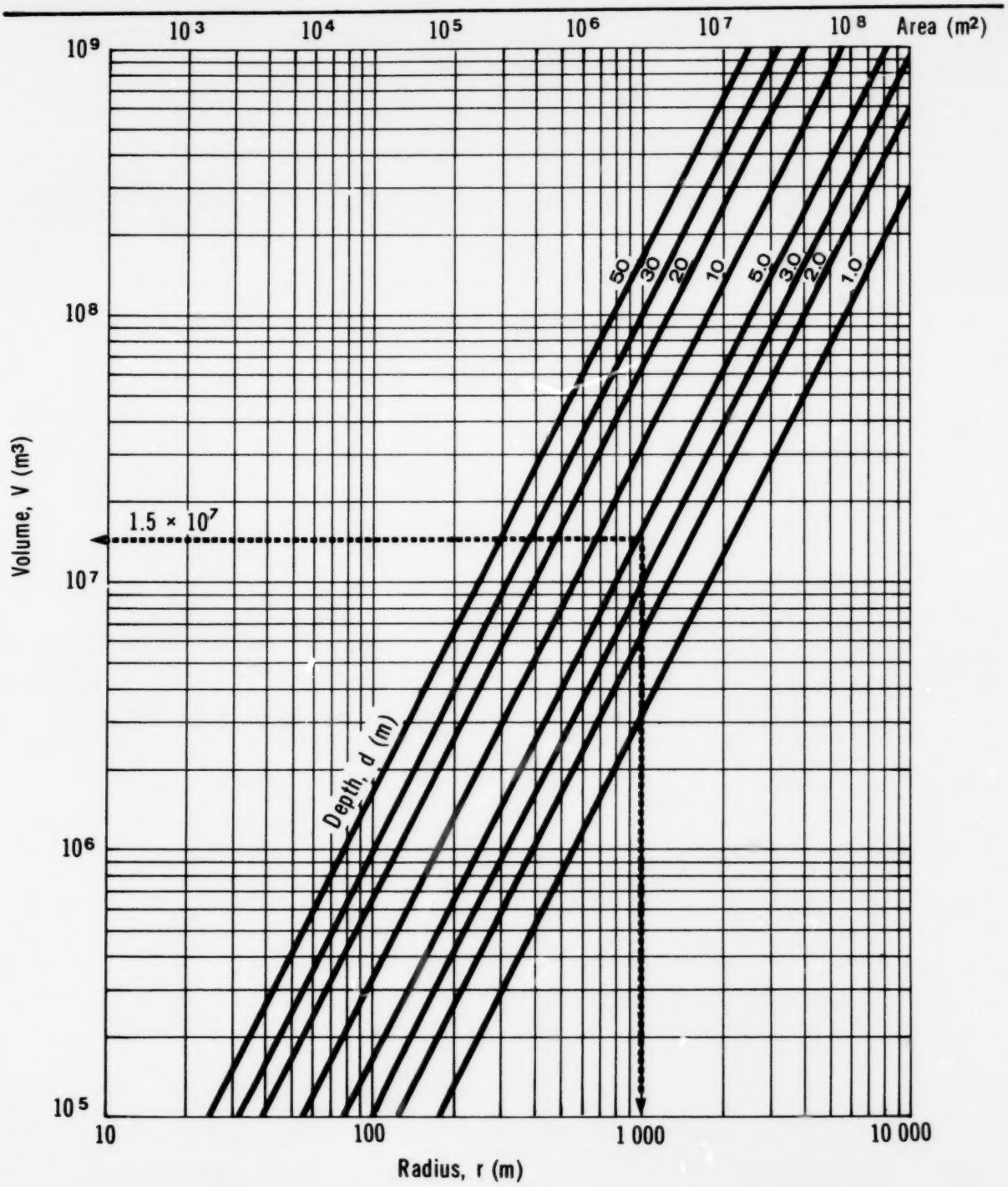
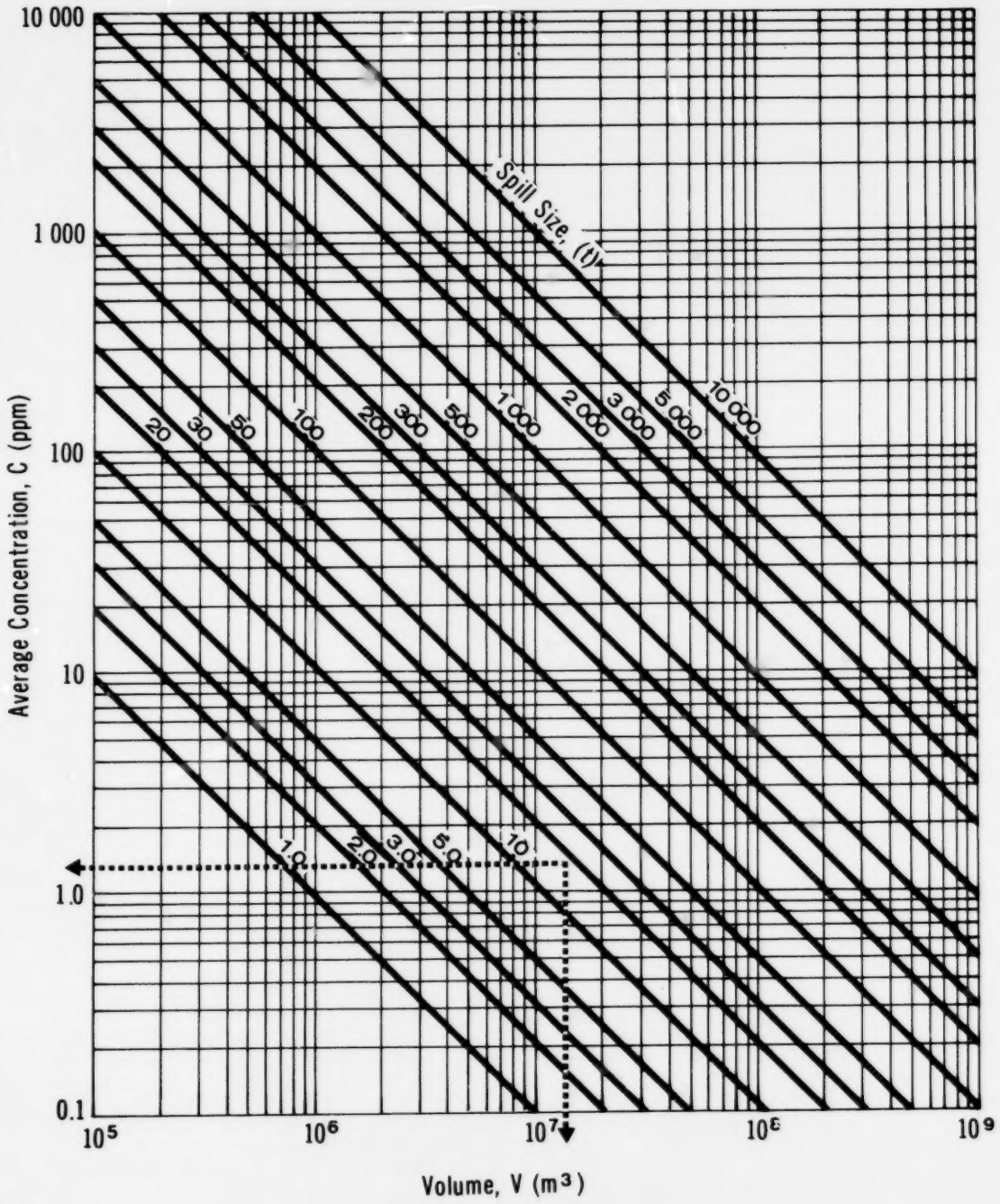


FIGURE 19

ETHYLENE GLYCOL

AVERAGE CONCENTRATION vs VOLUME



Solution

Step 1: Define parameters

- W = 50 m
- d = 5 m
- U = 1 m/s
- Spill mass = 20 tonnes of ethylene glycol

Step 2: Calculate the time to reach the point of interest

- Use Figure 12
- With X = 5000 m and U = 1 m/s, t = 83 min

Step 3: Calculate the hydraulic radius (r)

- Use Figure 13
- With W = 50 m and d = 5 m, r = 4.2 m

Step 4: Calculate the longitudinal diffusion coefficient (E)

- Use Figure 14
- With r = 4.2 m and U = 1 m/s, E = 69 m^2/s

Step 5: Calculate alpha (α)

- Use Figure 15
- With E = 69 m^2/s and t = 83 min, (α) = 2000

Step 6: Calculate delta (Δ)

- Use Figure 16
- With alpha (α) = 2000 and mass = 20 tonnes, delta (Δ) = 10

Step 7: Compute the stream cross-sectional area (A)

- A = W x d = 50 x 5 = 250 m^2

Step 8: Calculate the maximum concentration (C) at the point of interest

- Use Figure 17
- With Δ = 10 and A = 250 m^2, C = 40 ppm

5.4.3.2 Average pollutant concentration in lakes or still water bodies. A 20 tonne spill of ethylene glycol has occurred in a lake. The point of interest is located on the shore

approximately 1000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

Solution

Step 1: Define parameters

- d = 5 m
- r = 1000 m
- spill size = 20 tonnes

Step 2: Determine the volume of water available for dilution

- Use Figure 18
- With r = 1000 m, d = 5 m, the volume is approximately 1.5×10^7 m^3

Step 3: Determine the average concentration

- Use Figure 19
- With V = 1.5×10^7 m^3 and spill mass = 20 tonnes, the average concentration is 1.5 ppm

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Mechanisms. The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of ethylene glycol onto soil and its transport downward through the soil are presented here.

Ethylene glycol is shipped as a liquid, either pure or diluted with water to various concentations. When the pure liquid is spilled onto the soil, it will infiltrate slowly because of its high viscosity. More dilute solutions, either as shipped or as created on site due to precipitation or flushing with water, will infiltrate more quickly. If the soil surface is saturated with moisture at the time of the spill, as might be the case after a rainfall, the spilled chemical will run off or remain ponded.

For this work, the soils have been assumed to be at field capacity (the maximum amount of water the soil can hold after the excess is drained). This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents "worst case" analysis.

During transport through the soil, ethylene glycol can interact with some of the soil material by means of adsorption. Biodegradation can also occur to some degree.

However, significant amounts are expected to remain for transport down toward the groundwater table. The analysis used here neglects these retarding factors.

Upon reaching the groundwater table, the contaminant will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with dilution and diffusion serving to reduce the concentration somewhat. This is shown schematically in Figure 20.

5.5.2 Equations Describing Ethylene Glycol Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Ethylene Glycol in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

where: k = intrinsic permeability of the soil (m^2)

ρ = mass density of the fluid (kg/m^3)

μ = absolute viscosity of the fluid (Pa·s)

g = acceleration due to gravity = 9.81 m/s^2

The fluids involved are pure and 10 percent by weight ethylene glycol, and water. The water calculations represent the extreme as dilution occurs. The appropriate properties of ethylene glycol are given in the following chart:

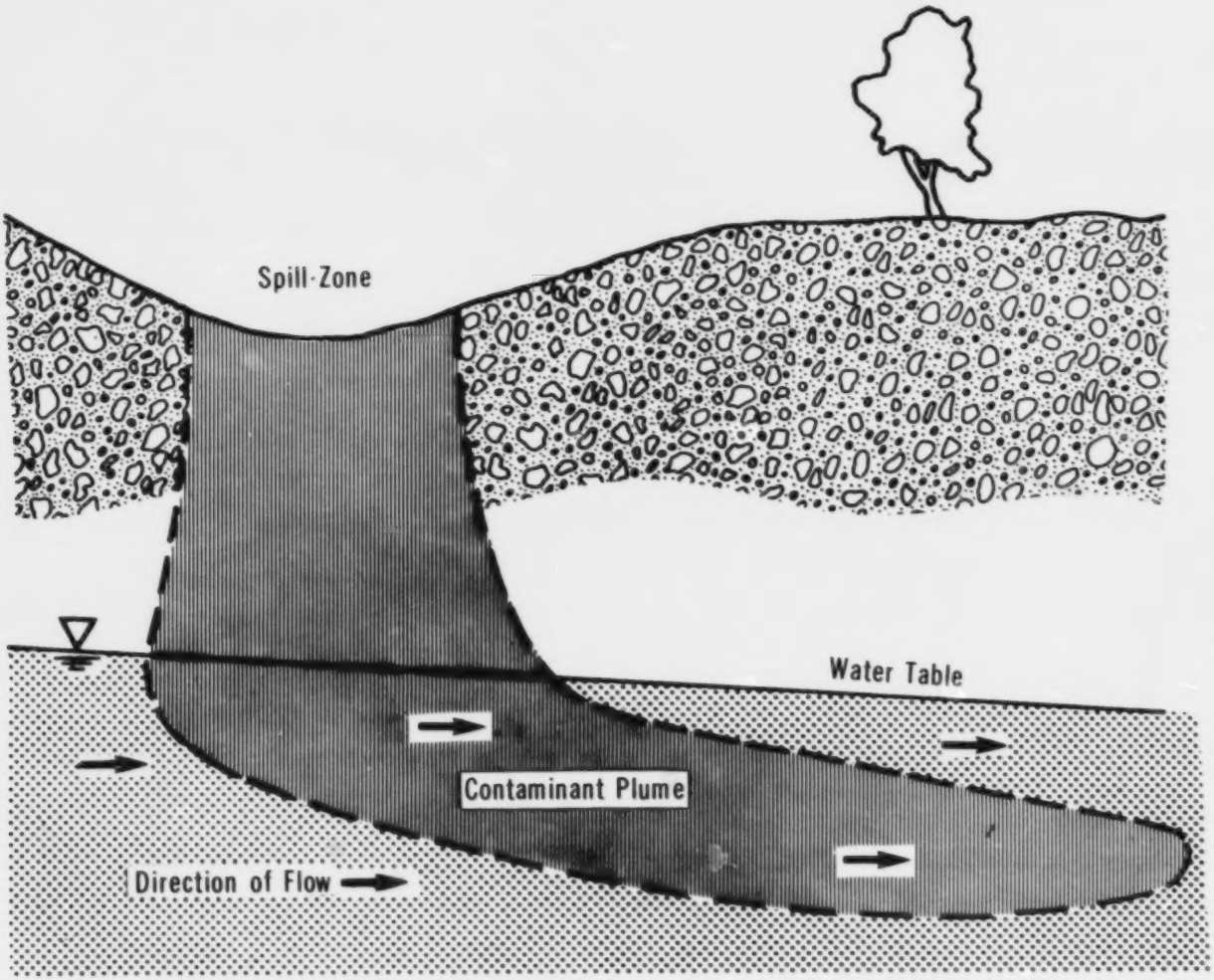
	Ethylene Glycol		
Property	Pure (20°C)	10% by Wt. (20°C)	Water (20°C)
Mass density (ρ), kg/m^3	1113	1011	998
Absolute viscosity (μ), Pa·s	19.9×10^{-3}	1.28×10^{-3}	1.0×10^{-3}
Saturated hydraulic conductivity (K_o), m/s	$(0.05 \times 10^7)k$	$(0.78 \times 10^7)k$	$(0.98 \times 10^7)k$

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

FIGURE 20

ETHYLENE GLYCOL

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity (n) = 0.35

–Intrinsic Permeability (k) = 10^{-9} m^2

–Field Capacity (θ_{fc}) = 0.075

Property	Soil Type		
	Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability, (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45

5.5.5 Penetration Nomograms. Nomograms for the penetration of ethylene glycol into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time (t_p) plotted against depth of penetration (B). Because of the methods and assumptions used, the penetration depth should be considered as a maximum depth in time t_p. A flowchart for the use of nomograms is presented in Figure 21. The nomograms are presented as Figures 22, 23 and 24.

The water line on the nomograms represents the maximum penetration of water at 20°C in time t_p. It is a limiting condition as ethylene glycol becomes diluted with water from precipitation or flushing.

5.5.6 Sample Calculation. A 20 tonne spill of ethylene glycol has occurred on coarse sand. The temperature is 20°C; the spill radius is 8.6 m. Calculate the depth of penetration 150 minutes after the spill.

Solution

Step 1: Define parameters

- Mass spilled = 20 000 kg (20 tonnes)
- T = 20°C
- r = 8.6 m
- Soil = coarse sand
- Groundwater table depth (d) = 13 m
- Time since spill (t_p) = 150 min

Step 2: Calculate area of spill

- $A = \pi r^2 = 232\ m^2$

Step 3: Estimate depth of penetration (B) at time (t_p)

- For coarse sand, B = 4.9 m at t_p = 150 min
- Groundwater table has not been reached in this time

FIGURE 21

ETHYLENE GLYCOL

FLOWCHART FOR NOMOGRAM USE

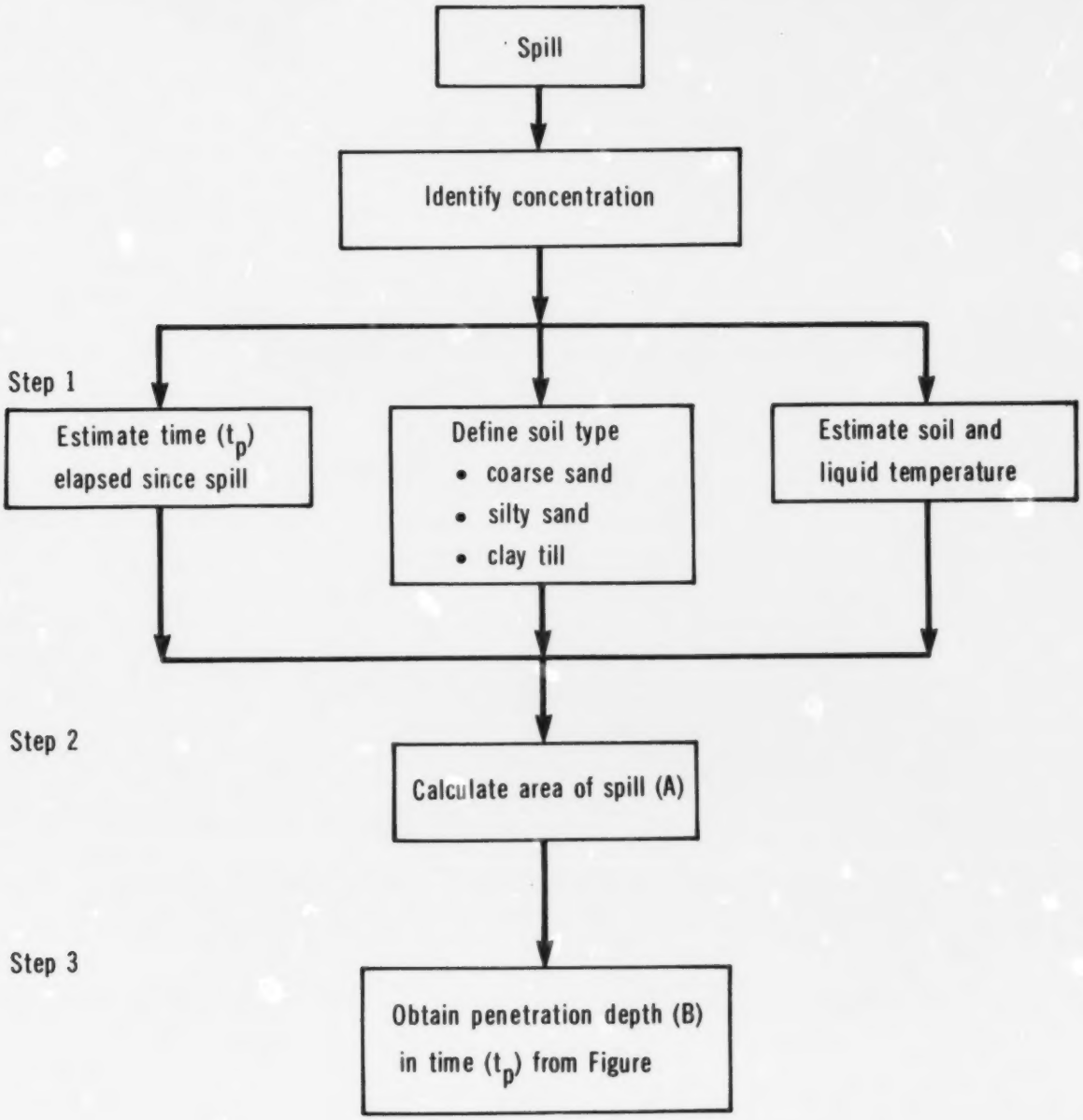


FIGURE 22

ETHYLENE GLYCOL

PENETRATION IN COARSE SAND

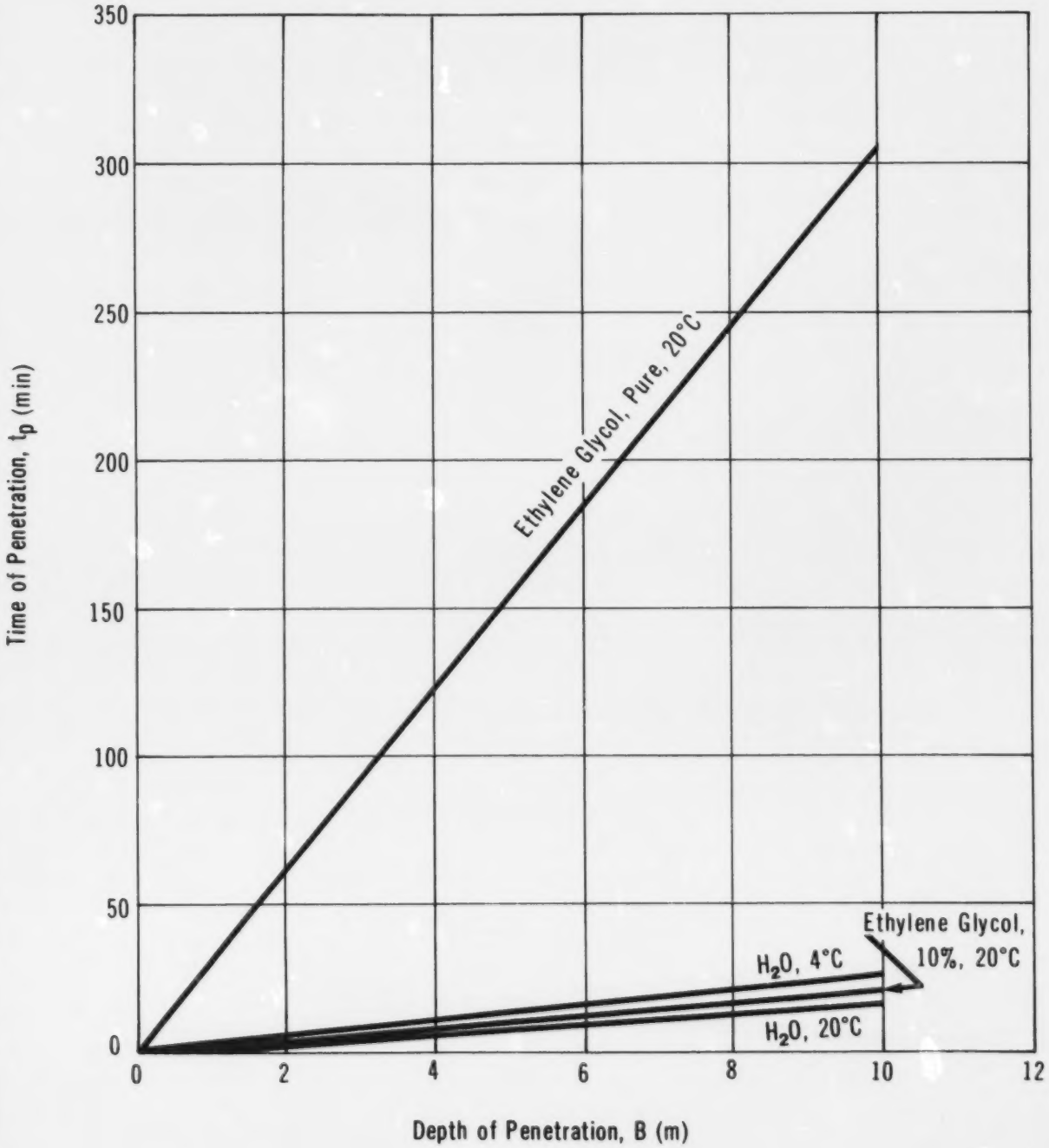


FIGURE 23

ETHYLENE GLYCOL

PENETRATION IN SILTY SAND

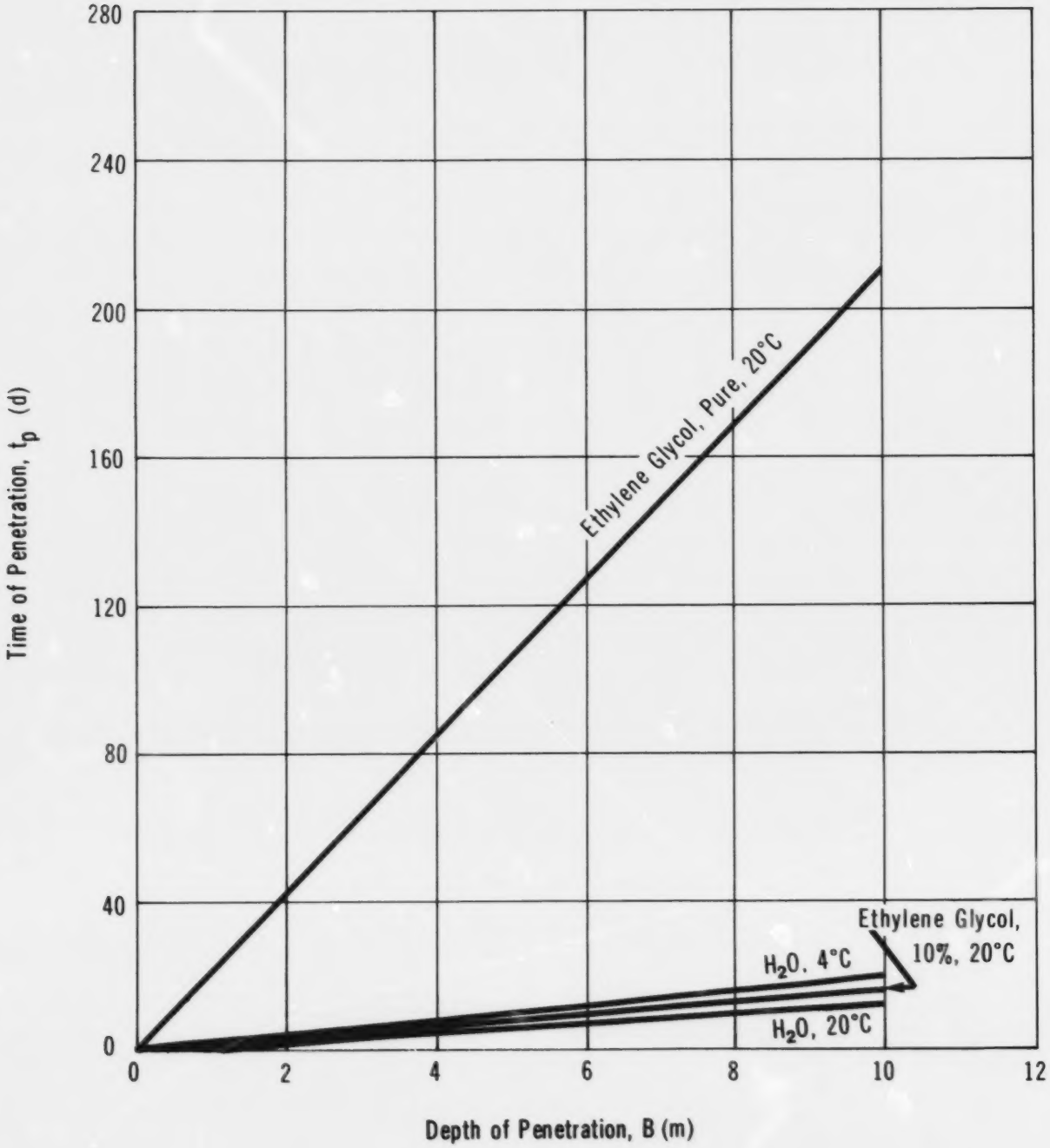
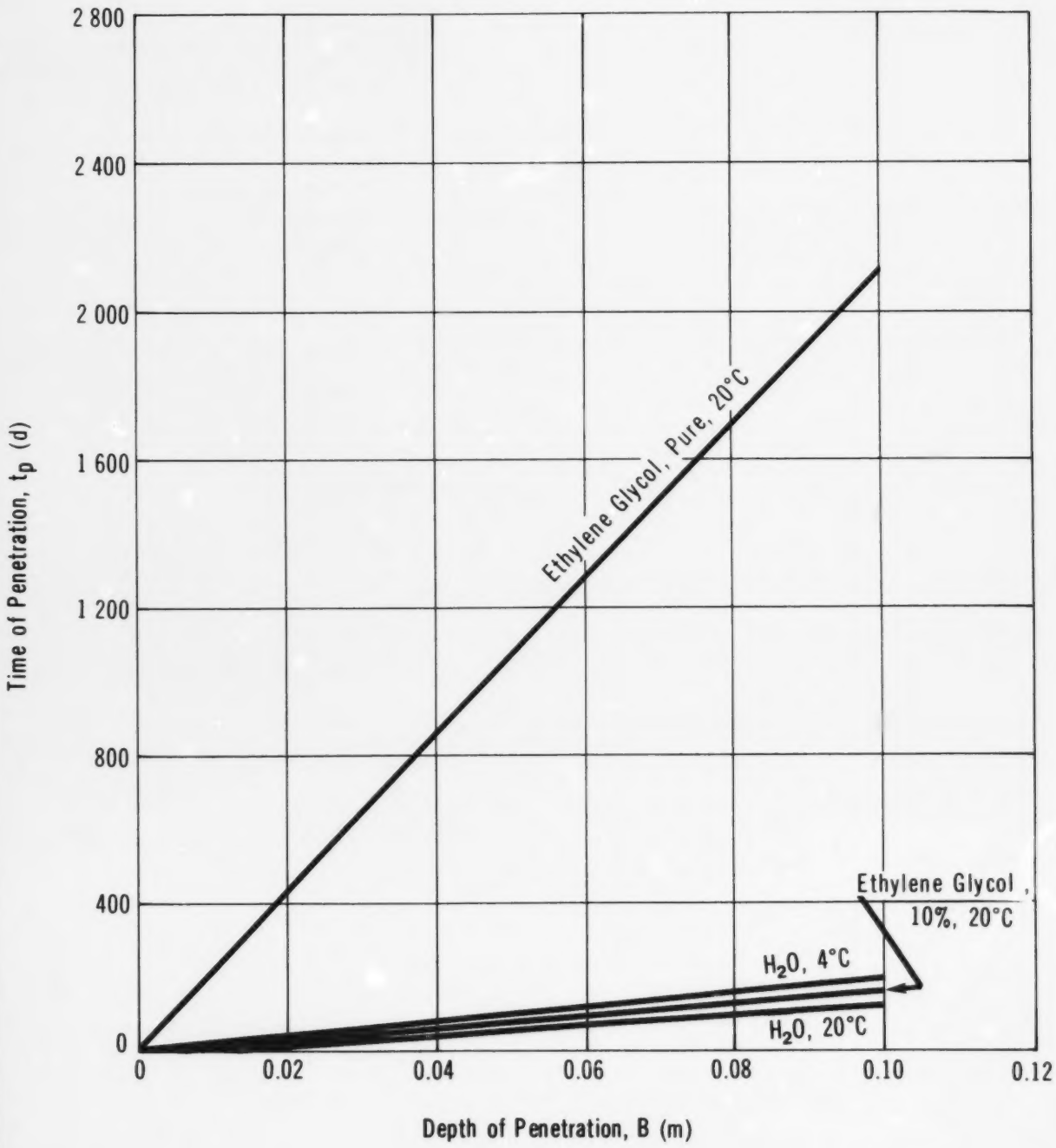


FIGURE 24

ETHYLENE GLYCOL

PENETRATION IN CLAY TILL



6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. Canada has no suggested or regulated limits for ethylene glycol in water. No standards exist in the USA. However, the U.S. EPA has suggested a permissible ambient goal of 140 µg/L (0.14 mg/L) based on health effects (Noyes 1981).

6.1.2 Air. No limits have been set in Canada for ethylene glycol levels in air. West Germany regulates emissions of ethylene glycol in waste gas flues to under 300 mg/m^3 if the flue rate is 6 kg/h or higher (Miller 1979).

6.2 Aquatic Toxicity

6.2.1 U.S. Toxicity Rating. Ethylene glycol has been assigned a TLm^{96} of 100 to 1000 ppm (RTECS 1979).

6.2.2 Measured Toxicities.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Kill Data					
2000 to 3000	-	Fish	lethal	-	Serkowitz 1973
Fish Toxicity Tests					
49 300	168	Guppy (*Poecilia reticulata*)	LC_{50}	-	Verschueren 1984
<5000	24	Goldfish	LC_{50}	20°C, static	JWPCF 1980
18 500	96	Rainbow trout	LC_{50}	-	Jank 1974
41 000	96	Rainbow trout	LC_{50}	12°C	Johnson 1980
Invertebrates					
>20 000	24	Brine shrimp (*Artemia salina*)	TL_m	static	Price 1974
>100	48	Brown shrimp (*Crangon crangon*)	LC_{50}	aerated, salt water	Portman 1970

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Microorganisms					
>10 000	-	Green algae (*Scenedesmus quadricauda*) Protozoa (*Entosiphon sulcatum*)	inhibition of cell multiplication in all species	-	Verschueren 1984
	-	Bacteria (*Pseudomonas putida*)			
250	-	Bacteria (*Pseudomonas*)	toxic	-	Verschueren 1984
180 000	-	Algae (*Chlorella pyrenoidosa*)	toxic	-	Verschueren 1984

6.3 Mammalian Toxicology

A dose of 2 to 10 mL/kg taken orally is toxic to cattle (Crowell 1979).

6.4 Avian Toxicity

Poisoning has occurred in ducks due to antifreeze ingestion. Oral doses of 1.1 to 17.8 mL/kg led to increasing tissue concentration of glycol and decreased time-to-death (Stowe 1981).

6.5 Plant Toxicity

Oat (*Avena sativa*) coleoptile segments were exposed to 0.5-3 percent aqueous solutions of ethylene glycol; the exposure resulted in the inhibition of elongation of these segments (Miller 1979). Treatment of maize microsporocytes (corn spores) with ethylene glycol produced aberrant chromosome behaviour (Miller 1979).

6.6 Degradation

B.O.D. kg/kg	B.O.D. % Theor.	Days	Seed	Method	Reference
-	34	5	Sewage seed	freeshwater	Price 1974
-	100	20	Sewage seed	freshwater	Price 1974
-	20	5	Sewage seed	saltwater	Price 1974
-	77	20	Sewage seed	saltwater	Price 1974
>1	96	6	Pure bacterial	-	Ryerman 1966
<1	21.8	5	Activated sludge	-	Gerhold 1966
>1	40.2	1	Activated sludge	-	Gerhold 1966
-	12.5	5	Sewage seed	-	Gloyna 1963
-	78	20	Sewage seed	-	Gloyna 1963
0.16 to 0.68	-	5	Sewage seed	-	Henkelekian 1955
0.93 to 1.1	-	10	Sewage seed	-	Henkelekian 1955

Above 1000 mg/L, the C.O.D. removal rate decreases (Breszkiewicz 1979). In one study, ethylene glycol (2 or 10 mg/L) was biodegraded completely in 3 days when tested in four types of river water at 20°C (Miller 1979). When added to adapted activated sludge, 97 percent of a sample was degraded over 120 hours (Miller 1979). In another study, it was found that the bio-oxidation of ethylene glycol (up to 10 mg/L) was 34 percent in 5 days, 86 percent in 10 days, 92 percent in 15 days, and 100 percent in 20 days, when domestic waste water was used as seed. When synthetic seawater was used as seed, bio-oxidation was 20 percent in 5 days, 60 percent in 10 days, 65 percent in 15 days and 77 percent in 20 days (Miller 1979).

6.7 Long-term Fate and Effects

Ethylene glycol biodegrades completely in a matter of 20-40 days (Miller 1979). No potential for bioaccumulation or food chain contamination has been found (OHM-TADS 1981).

7 HUMAN HEALTH

Ethylene glycol is a syrup-like, hygroscopic liquid with a sweetish taste but little or no odour. Its physical properties make it a popular antifreeze additive, and a good cooling system and hydraulic brake fluid. It finds further industrial applications as a humectant, in plastics production, in formulations of inks, and as a softening agent for cellophane. Its low vapour pressure virtually excludes the presence of significant amounts of vapour at room temperature; however, at elevated temperatures, adverse effects have been reported due to exposure to ethylene glycol mist (Doc. TLV 1981).

Ethylene glycol is capable of inducing minor local injury; its major toxic effects are systemic in nature, with percutaneous absorption possibly contributing to intoxication (USDHEW 1977). Accidental ingestion cases have allowed the documentation of adverse health effects in humans due to this route of exposure.

This chemical has shown positive mutational effects in tests with bacteria and algae (Verschueren 1984). It was selected for carcinogenic bioassay by the U.S. National Cancer Institute (NCI) at the joint request of the U.S. Food and Drug Administration and the U.S. NCI in 1980 (USDHEW 1980). No results have as yet been reported. Ethylene glycol has been included in the U.S. EPA TSCA Inventory.

The toxicological data summarized here have been extracted from reliable standard reference sources. It should be noted that some of the data are for chronic (long-term), low-level exposures and may not be directly applicable to spill situations.

7.1 Recommended Exposure Limits

Exposure standards for ethylene glycol have been established to minimize irritation of the respiratory passages by both the mist and vapour forms of ethylene glycol (Doc. TLV 1981). Deletion of the particulate exposure value was included in the 1983 ACGIH list of intended changes. Canadian provincial guidelines generally are similar to those of the USA-ACGIH, unless indicated otherwise.

Guideline (Time)	Origin	Recommended Level	Reference
Time-weighted Averages (TWA)			
TLV-Ceiling - Vapour	USA-ACGIH	50 ppm (125 mg/m^3)	TLV 1983

Guideline (Time)	Origin	Recommended Level	Reference
Concentration moyenne (aérosol)	Quebec	10 mg/m^3	Quebec 1979
Concentration moyenne (vapeur)	Quebec	100 ppm (250 mg/m^3)	Quebec 1979
TWAEC	Ontario	No exposure limit stated	Ontario 1981
TLV	-	100 ppm	CHRIS 1978
MAC-suggested	Soviet Union	5.0 mg/m^3	Filatova 1981
Short-term Exposure Limits (STEL)			
STEL (15 min) - Particulate	USA-ACGIH	20 mg/m^3	TLV 1983
Ceiling - Vapour	USA-ACGIH	50 ppm (125 mg/m^3)	TLV 1983
Concentration maximale (aérosol)	Quebec	20 mg/m^3	Quebec 1979
Concentration maximale (vapeur)	Quebec	125 ppm (325 mg/m^3)	Quebec 1979
Other Human Toxicities			
IDLH		1000 ppm	NIOSH Guide 1978
TD_{LO} (child)		7400 mg/kg	RTECS 1979
LD_{LO}		1637 mg/kg	DPIMR 1981
LD		1.4 mL/kg	Doull 1980
LD		100 mL	DPIMR 1981

Inhalation Toxicity Index

The Inhalation Toxicity Index (ITI) is a measure of the potential of a substance to cause injury by inhalation. It is calculated as follows:

ITI = 1315.12 (Vapour Pressure, in mm Hg/TLV•, in ppm)

At 25°C, ITI = 1315.12 (7.5×10^{-2}/50 ppm)

At 25°C, ITI = 2

7.2 Irritation Data

7.2.1 Skin Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified	Liquid and solid forms are practically harmless to the skin	CHRIS 1978
SPECIES: Rabbit		
555 mg	Mild irritation (open skin)	DPIMR 1981

7.2.2 Eye Contact

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified	Vapours are nonirritating to the eyes at low levels	CHRIS 1978
SPECIES: Rabbit		
12 mg/m^3 (3 d)	Moderate to severe irritation	Doull 1980
1440 mg (6 h)	Moderate irritation	RTECS 1979
111 mg	Irritation	DPIMR 1981
SPECIES: Rat		
12 mg/m^3 (24 h)	Corneal opacity and apparent blindness within 8 days of initiation of exposure	Doull 1980

7.3 Threshold Perception Properties

7.3.1 Odour. Odourless (Doc. TLV 1981).

7.3.2 Taste. Taste Characteristics: Sweetish taste (USDHEW 1977).

7.4 Toxicity Studies

7.4.1 Inhalation.

Exposure Level (and Duration)	Effects	Reference
Acute Exposures		
SPECIES: Human		
10 000 mg/m^3	Irritation	DPIMR 1981
Unspecified	Very toxic in particulate form upon inhalation. Direct exposure causes headache, nausea, dizziness and affects kidneys	DPIMR 1981
SPECIES: Rat, Guinea Pig		
256 mg/m^3 (sat. conc. at 25°C) (12 d)	One mortality of 15 rats and one mortality of 3 guinea pigs	Miller 1979
Chronic Exposures		
SPECIES: Human		
12 ppm mean concentration (30 mg/m^3) (20-22 h/d, for 4 wk)	Aerosolized ethylene glycol produced irritation of the throat, mild headache and low backache, but on the whole the exposure was very well tolerated. Complaints became marked when the exposure chamber concentration was raised to 140 mg/m^3 for part of a day. Concentrations of 80 ppm or greater produced burning sensation along trachea and burning cough. Irritative phenomena became common when concentration reached 60 ppm	Doc. TLV 1981

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
Acute Exposures		
SPECIES: Human		
7400 mg/kg	Oral TD_{LO} for children causing systemic toxic effects	DPIMR 1981
1400-1600 mg/kg	Lethal dose	Miller 1979
710 mg/kg	Oral LD_{LO}	DPIMR 1981
1.4 mL/kg (1550 mg/kg)	Lethal oral dose	Doull 1980
SPECIES: Dog		
7 g/kg	Minimum lethal dose	Doull 1980
SPECIES: Cat		
2000 mg/kg	LD_{50}	DPIMR 1981
1 g/kg	Minimum lethal dose	Doull 1980
SPECIES: Rabbit		
9 g/kg	Minimum lethal dose	Doull 1980
SPECIES: Guinea Pig		
6100 to 8100 mg/kg	LD_{50} average	Miller 1979
6610 mg/kg	LD_{50}	RTECS 1979
7.35 mL/kg	LD_{50}	Verschueren 1984
SPECIES: Rat		
8540 mg/kg	LD_{50}	DPIMR 1981
6100 to 8540 mg/kg	LD_{50} average	Miller 1979
5840 mg/kg	LD_{50}	RTECS 1979
5.50 mL/kg	LD_{50}	Verschueren 1984

Exposure Level (and Duration)	Effects	Reference
SPECIES: Mouse		
8300 to 15 300 mg/kg	LD_{50} average	Miller 1979
7500 mg/kg	LD_{50}	DPIMR 1981
13.7 g/kg	LD_{50}	Verschueren 1984

7.4.3 Skin. Ethylene glycol can be absorbed through the intact skin. Only systemic effects as a result of skin exposure are reported in this section.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified (4 mo)	Industrial worker developed eczematous dermatitis after contacting 25 percent solution	Miller 1979
SPECIES: Rabbit		
19 530 mg/kg	LD_{50}	DPIMR 1981

7.4.4 Subcutaneous.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Cat		
2000 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Guinea Pig		
5000 mg/kg	LD_{LO}	DPIMR 1981

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
6400 mg/kg (intraperitoneal)	LD_{50}	Miller 1979
5300 mg/kg	LD_{50}	DPIMR 1981
SPECIES: Mouse		
6700 mg/kg	LD_{50}	Miller 1979
5600 mg/kg (intraperitoneal)	LD_{50}	Miller 1979
4400 mg/kg (intravenous)	LD_{50}	Miller 1979

7.4.5 Mutagenicity, Teratogenicity, Carcinogenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Mouse		
26 mg (single dose)	No increased tumour incidence	Miller 1979
1-10 mg (single doses)	Group of 400 mice, no increased tumour incidence	Miller 1979
SPECIES: Rat		
30-100 mg/kg (single dose) (per wk for 1 yr)	No increase in tumour incidence	Miller 1979
SPECIES: *Salmonella typhimurium*		
Unspecified	No revertants, no sign of mutagenicity	Miller 1979

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their

sources indicated. Studies of ethylene glycol poisoning have shown a three-phase syndrome (Miller 1979): 1) central nervous system depression in 0.5-12 hours manifested by intoxication, nausea, vomiting, and in extreme cases by coma and death; 2) cardiopulmonary failure if victim survives phase 1. This usually occurs 12-18 hours after the ingestion and is manifested by cardiopulmonary failure, coma and death; and 3) renal failure, if the victim survives the last phase.

7.5.1 Inhalation.

1. Anorexia (Doull 1980).
2. Oliguria (USDHEW 1977).
3. Absolute lymphocytosis (Doull 1980).
4. Nystagmus.
5. Central nervous system depression.
6. Hematopoietic dysfunction (USDHEW 1977).
7. Loss of consciousness.
8. Pulmonary edema (GE 1980).

7.5.2 Ingestion.

1. Weakness.
2. Dizziness.
3. Abdominal pain.
4. Nausea and vomiting.
5. Spasmodic motion of the eyeball (GE 1980).
6. Tremor and convulsion (ITII 1981).
7. Areflexia (ITII 1981).
8. CNS stimulation followed by depression.
9. Narcosis (Goodman and Gilman 1980).
10. Cyanosis (ITII 1981).
11. Oxaluria (Doull 1980).
12. Albuminuria (ITII 1981).
13. Hematuria (ITII 1981).
14. Renal failure (Goodman and Gilman 1980).
15. Cardiac failure (USDHEW 1977).
16. Brain damage (USDHEW 1977).
17. Coma (Goodman and Gilman 1980).

18. Death.

7.5.3 Skin Contact.

1. Percutaneous skin absorption may contribute to intoxication (USDHEW 1977).

7.5.4 Eye Contact.

1. Irritation.
2. Conjunctivitis (ITII 1981).

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Ethylene Glycol with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Fire		•												Sax 1979
Heat		•											Combustible at high temperature (>110°C)	Sax 1979
SPECIFIC CHEMICALS														
Chlorosulphonic Acid	•						•						In a closed container	NFPA 1978
Oleum	•						•						In a closed container	NFPA 1978
Perchloric Acid			•		•								Decomposition of ethylene glycol. Decomposition has explosive violence in the presence of water	Bretherick 1979
Phosphorus Pentasulphide	•		•											Bretherick 1979
Sulphuric Acid	•						•						With 96 percent H_2SO_4 in a closed container	NFPA 1978

8.1 **Compatibility of Ethylene Glycol with Other Chemicals and Chemical Groups** (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
CHEMICAL GROUPS														
Alkali and Alkaline Earth Metals	•		•		•					•				EPA 600/2-80-076
Isocyanates	•													EPA 600/2-80-076
Nitrides		•	•										Nitrides may be detonated by heat of reaction	EPA 600/2-80-076
Reducing Agents		•	•	•										EPA 600/2-80-076

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been presented essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. It is recognized that countermeasures are dependent on the situation, and thus what may appear to be conflicting information may in fact be correct for different situations. These procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Ethylene glycol is a combustible liquid (Olin MSDS 1979).

9.1.2 Fire Extinguishing Agents. Use water spray to cool containers involved in a fire (Dow ERIS 1980)

Small fires: dry chemical or CO_2

Large fires: water fog or spray or alcohol foam (Dow ERIS 1980).

9.1.3 Spill Actions.

9.1.3.1 General. Little Inc. has performed a risk study for ethylene glycol transportation in the United States. The following is a summary of the overall exposure likelihoods (Miller 1979):

	Truck	Rail
Spill Pool Radius	17 m	32 m
Hazard Radius	17 m	32 m
Hazard Area	890 m^2	3200 m^2
Expected Number of Annual Spills	0.94	0.055
Recurrence Interval (years)	71.4	

9.1.3.2 Spills on land. For small spills, soak up with dry absorbent material and shovel into covered container for disposal (Olin MSDS 1979). Perlites and vermiculites are also recommended as in situ sorbents (OHM-TADS 1981).

For larger spills, contain if possible by forming mechanical and/or chemical barriers to prevent spreading (EPA 670/2-75-042). Application of a fly ash or cement powder to absorb the liquid bulk is recommended (EPA 670/2-75-042). Liquid can be recovered with pumps or vacuum equipment.

9.1.3.3 Spills in water. Contain if possible. Application of activated carbon at 10 percent the spill amount over the region occupied by 10 mg/L or greater concentrations is recommended (EPA 670/2-75-042). If recovery is impossible, consideration to in situ bacterial treatment should be given (Miller 1979). To protect aquatic life in situations where it cannot be removed, dilution may be considered.

9.1.4 Cleanup and Treatment.

9.1.4.1 General. Biological treatment has shown possible applicability for spill countermeasures by removing 97 percent of ethylene glycol in contaminated water (TSA 1980). A number of species have been found to degrade ethylene glycol or to catabolize it, including *Acinetobacter*, *Flavobacterium*, *Achromobacter*, *Mycobacterium*, *Pseudomonas*, *Sarcina* and *Xanthomonas* (Miller 1979).

9.1.5 Disposal. Waste ethylene glycol must never be discharged directly into sewers or surface waters. Large quantities of liquids may be disposed of by mixing with more flammable solvents and atomizing into an incinerator (GE 1980). Biological treatment, either at the spill site or at a water management facility, may also be considered.

9.1.6 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spilled material is known to be ethylene glycol:

- Safety glasses or goggles, NIOSH/OSHA-approved self-contained breathing apparatus and impervious clothing should be worn (GE 1980).
- Rubber or neoprene is recommended for gloves and boots (GE 1980; Olin MSDS 1979).
- The following clothing materials have breakthrough times of greater than 1 hour: natural rubber, neoprene, nitrile, polyethylene, polyurethane, polyvinyl chloride. The following materials have breakthrough times of about 1 hour: butyl rubber, neoprene with natural rubber, PVC-coated nitrile, chlorinated polyethylene, polyvinyl alcohol, styrene-butadiene rubber and Viton (Little 1983).
- Eye wash stations and chemical safety showers should be readily available in areas of use and spill situations (GE 1980).

9.1.7 Storage Precautions. Store material in mild steel containers, except where colour requirements are most critical. Then store in resin-coated steel, glass, aluminum or stainless steel containers. Close containers tightly to avoid moisture. Separate from oxidizing materials (GE 1980).

10 PREVIOUS SPILL EXPERIENCE

10.1 General

This section contains information on previous spill experience which will be useful to readers in understanding spill response and countermeasures. Only those which meet the criteria are included, and thus, the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

10.2 Tanker Truck Spill (PC AEWQD 1982)

A tanker truck carrying approximately 23 000 L of 60 percent ethylene glycol antifreeze solution overturned into a roadside bog, spilling 60 percent of its contents. A soil bank incorporated in the bog contained and prevented some of the spilled material from reaching a nearby creek. An area of approximately 180 m^2 (30 m long by 6 m wide) was contaminated by the spill.

Cleanup crews arrived at the site several hours later and pumped about 11 000 L of the contained material into vacuum trucks. The crew then dug two trenches (6 m long, 3 m wide, 0.5 m deep) around the spill site to intercept any possible migration through the soil. Collected material was pumped out every 3 days for a period of 2 weeks. Two truck loads of contaminated soil were excavated from the spill site and disposed of at a nearby landfill. Fresh soil was then applied to the area and seeded.

Vegetation damage was mainly superficial in the area of the site. Water samples taken upstream and downstream of the spill's influent into the river revealed no detectable increase in total organic carbon.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for the analysis of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Ethylene Glycol in Air

11.1.1 Gas Chromatography (NIOSH 1981). A range of 4.2 to 327 mg/m^3 (1.65-128.81 ppm) of ethylene glycol in air may be determined by gas chromatography using flame ionization detection.

A known volume of air is drawn through a three-stage sampler consisting of a glass fibre filter followed by two sections of 20/40 mesh silica gel. The glass fibre filter is 13 mm in diameter and is housed in a 13 mm holder. The two sections of silica gel are contained in a 8 cm x 8 mm O.D. glass tube. The first section contains 520 mg of 20/40 mesh silica gel, whereas the second section contains 260 mg. The sections are separated by a plug of urethane foam. A sample volume of 3 L at a flow rate of 200 mL/min is recommended.

The glass fibre filter is desorbed in 1 mL of 2 percent propanol contained in a 1 mL glass vial with a rubber cap. The silica gel sections are transferred to separate 1 mL glass vials each containing 1 mL of 2 percent propanol. The samples are allowed to desorb for 5 min with slight agitation.

Each stage of the sampling train is analyzed separately by injecting a 1 µL aliquot into a suitable gas chromatograph equipped with a flame ionization detector. The ethylene glycol is determined by an electronic integrator which measures peak areas, and a calibration curve. The column is 1.9 m x 2 mm I.D. glass packed with 3 percent Carbowax 20M on 80/100 mesh Chromosorb 1.

Typical gas chromotograph operating conditions are: helium carrier gas at 31 mL/min, hydrogen flow at 44 mL/min, air flow at 304 mL/min, column temperature at 165°C, injector temperature at 250°C, detector temperature at 300°C.

11.2 Qualitative Method for the Detection of Ethylene Glycol in Air

The sample is collected as in Section 11.1.1 and desorbed with Freon 113• (1,1,2-trichloro-1,2,2-trifuoroethane). The sample is scanned on a suitable double-beam recording I.R. spectrophotometer using matched 1 cm cells. The presence of characteristic absorption bands (in the 3200 to 2700 cm^{-1} range) indicates ethylene glycol (NIOSH 1981; AWWA 1981).

11.3 Quantitative Method for the Detection of Ethylene Glycol in Water

11.3.1 Partition Infrared (AWWA 1981). A range of 40 to 400 ppm of ethylene glycol in water may be determined using partition infrared spectrophotometry.

A minimum of 1 L of representative sample is collected in an appropriate container. The sample is acidified to pH 2 or lower with dilute hydrochloric acid. A 5 mL volume should be sufficient. The sample is transferred to a separatory funnel and a 30 mL volume of Freon• 113 (1,1,2-trichloro-1,2,2-trifluoroethane) is added after it is used to rinse the sample container. The solvent layer is drained into a 100 mL volumetric flask. Two more 30 mL Freon• 113 extractions are carried out and the extract combined in the 100 mL volumetric flask. The volume is adjusted to 100 mL with Freon• 113.

The sample is scanned on a suitable infrared spectrophotometer from 3200 cm^{-1} to 2700 cm^{-1} using matched 1 cm near-infrared silica cells. The sample concentration is determined from a calibration curve.

11.4 Qualitative Method for the Detection of Ethylene Glycol in Water

The sample is collected and extracted as in Section 11.3.1. The sample is scanned on a suitable infrared spectrophotometer from 3200 cm^{-1} to 2700 cm^{-1} using matched near-infrared silica cells. The presence of characteristic absorption bands indicates the presence of ethylene glycol (AWWA 1981).

11.5 Quantitative Method for the Detection of Ethylene Glycol in Soil

11.5.1 Partition Infrared (AWWA 1981). This method is used for the detection of concentrations greater than 40 ppm ethylene glycol in soil.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar and dried by the addition of magnesium sulphate. Freon• 113 (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract the ethylene glycol. Three extractions, using 30 mL of Freon• 113 each time, are carried out. The extracts are combined in a 100 mL volumetric flask. The volume is adjusted to 100 mL with Freon• 113. The sample is scanned on a suitable infrared spectrophotometer from 3200 cm^{-1} to 2700 cm^{-1} using matched 1 cm near-infrared silica cells. The sample concentration is determined from a calibration curve.

11.6 Qualitative Method for the Detection of Ethylene Glycol in Soil

The sample is collected and extracted as in Section 11.5.1. The sample is scanned on a suitable infrared spectrophotometer from 3200 cm^{-1} to 2700 cm^{-1} using matched 1 cm near-infrared silica cells. The presence of characteristic absorption bands indicates ethylene glycol (AWWA 1981).

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EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immission concentration
min	minute or minimum
mm	millimetre
µg	microgram
µm	micrometre
°Be	degrees Baumé (density)
MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_c	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_s	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_c	critical temperature
TC_{LO}	toxic concentration low
Td	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
Ts	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight